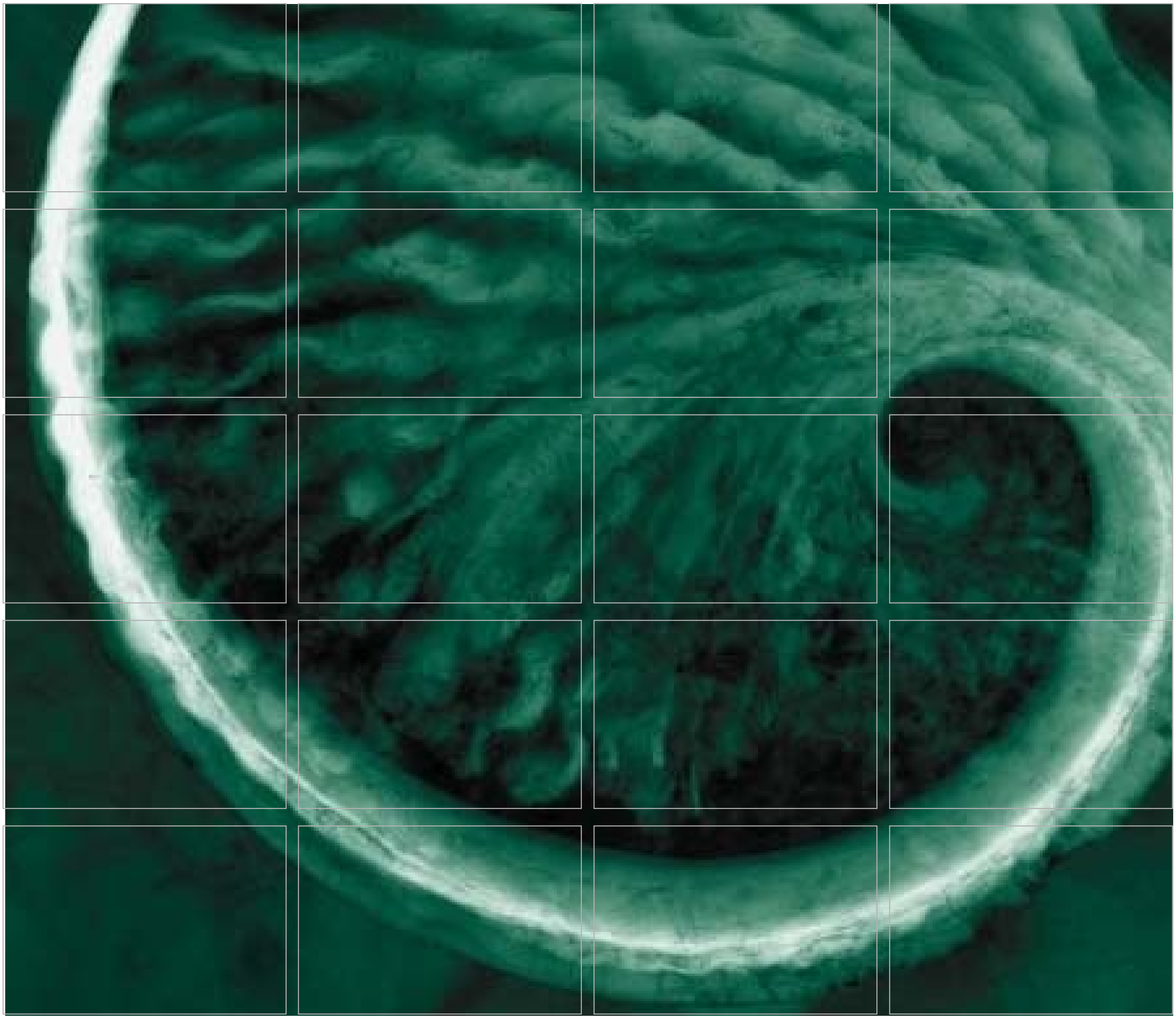

In Situ Chemical Oxidation Pilot Study Workplan

Hookston Station
Pleasant Hill, California

15 March 2007

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Prepared for:
Hookston Station
Responsible Parties

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Hookston Station Responsible Parties

In Situ Chemical Oxidation Pilot Study Workplan

Hookston Station
Pleasant Hill, California

15 March 2007

Project No. 0020557

Arun S. Chemburkar, P.E.
Senior Project Engineer

Brian S. Bjorklund, P.G.
Project Manager

Environmental Resources Management
1777 Botelho Drive, Suite 260
Walnut Creek, California 94596
T: 925-946-0455
F: 925-946-9968

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LIST OF ACRONYMS

$\mu g/L$	Microgram per liter
bgs	Below ground surface
CPT	Cone penetrometer testing
ERM	ERM-West, Inc.
HASP	Health and Safety Plan
ISCO	In situ chemical oxidation
$KMnO_4$	Potassium permanganate
MIP	Membrane interface probe
MSDS	Material safety data sheet
NaS_2O_8	Sodium persulfate
SOD	Soil oxidant demand
SOP	Standard Operating Procedure
TCE	Trichloroethene
USA	Underground Services Alert
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound

1.0 INTRODUCTION

On behalf of the Hookston Station Responsible Parties, ERM-West, Inc. (ERM) has prepared this *Workplan for In Situ Chemical Oxidation Pilot Study* (workplan) for the Hookston Station site located at 228 Hookston Road in Pleasant Hill, California (Figure 1). The Hookston Station Responsible Parties include Union Pacific Railroad Company, Daniel C. Helix, Mary Lou Helix, Elizabeth Young, John V. Hook, Steven Pucell, Nancy Ellicock, and the Contra Costa County Redevelopment Agency. Environmental investigations and remediation activities for the Hookston Station site have been conducted under regulatory oversight of the California Regional Water Quality Control Board (Water Board). All requirements of the Water Board Order Number R2-2003-0035 (16 April 2003) and amended Order Number R2-2004-0081 (15 September 2004) have been fulfilled. A new Order (R2-2007-0009) was adopted in January 2007 for the Hookston Station site that is focused on the site cleanup. This workplan is submitted in accordance with Task 2 of that Order.

1.1 DOCUMENT ORGANIZATION

This workplan is organized as follows:

- Section 1.0 presents the introduction, project background information, and objectives of the pilot study;
- Section 2.0 describes the chemical oxidation process;
- Section 3.0 outlines the specific activities involved with the implementation of the chemical oxidation pilot study;
- Section 4.0 discusses data evaluation and reporting;
- Section 5.0 provides a discussion of health and safety issues; and
- Section 6.0 presents a schedule for the pilot study implementation.

1.2 PROJECT BACKGROUND

In anticipation of the potential application of in situ chemical oxidation (ISCO) at the Hookston Station site, a chemical oxidation treatability study was initially conducted in October 2003 using site soils. The objective of the study was to evaluate the potential effectiveness of two commonly employed oxidants, potassium permanganate ($KMnO_4$) and sodium persulfate (NaS_2O_8), for the chemicals of concern that originate in whole or in part from the Hookston Station site.

The treatability study tested the total soil oxidant demand (SOD) of $KMnO_4$ and NaS_2O_8 to assess the ability of these two oxidants to cost-effectively remediate ground water impacted by chemicals originating from the site. SOD is one of the greatest factors affecting viability of ISCO, as the amount of organics in native soil material that is oxidizable can dictate the amount of oxidant required more often than the mass of the contaminants of concern. The results of the treatability study found that the SOD of B-Zone soil is relatively low for both permanganate and persulfate oxidants, and both oxidants would be viable for treatment of the chlorinated ethenes at the site. Due to its greater in situ stability and ease of use, however, $KMnO_4$ was identified as the preferred oxidant if an ISCO remediation program were implemented for B-Zone ground water.

Remedial technologies for the Hookston Station site were selected in the *Feasibility Study* (ERM, 10 July 2006), which was approved by the Water Board on 2 November 2006. The selected technologies include an ISCO program to address chemical impacts that originate from the Hookston Station site in B-Zone ground water.

1.3 PILOT STUDY OBJECTIVES

The objectives of the pilot study are to:

- Collect site-specific data on the ability to distribute the oxidant in the subsurface;
- Determine the field SOD;
- Collect data evaluating the appropriate lateral spacing for injection points for the full-scale ISCO program;
- Determine the volume and concentration of chemical oxidant to be injected during the full-scale ISCO remediation program; and
- Evaluate potential rebound of chemical concentrations following one injection of chemical oxidant to evaluate the solution strength and frequency for additional injections during the full-scale ISCO remediation program.

2.0 *CHEMICAL OXIDATION TECHNICAL BACKGROUND*

Several types of chemical oxidants are potentially applicable to the site including ozone, Fenton's Reagent, NaS_2O_8, and $KMnO_4$. In-depth information on available oxidants is outlined in *Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater* (The Interstate Technology & Regulatory Council, January 2005). For the purposes of this pilot study, $KMnO_4$ will be utilized as the chemical oxidant, based on the results of the Hookston Station chemical oxidation treatability study. $KMnO_4$ offers the following advantages:

- It has been documented to be effective against the site-specific chemicals of concern, including trichloroethene (TCE), cis-1,2-dichloroethene, and 1,1-dichloroethene;
- It is the most environmentally stable oxidant available;
- It is safer to handle with respect to its chemical characteristics and reactivity; and
- It is easy to monitor the distribution of $KMnO_4$ within the subsurface due to its distinct purple color.

The oxidative reaction between $KMnO_4$ and chlorinated alkenes, such as TCE, breaks the bonds between carbon atoms and dechlorinates the individual molecules, resulting in the production of carbon dioxide. The reaction between $KMnO_4$ and dissolved TCE is as follows:

$$C_2HCl_3 \text{ (TCE)} + 2KMnO_4 \rightarrow 2CO_2 + 2MnO_2 + 2K^+ + 3Cl^- + H^+$$

In this reaction, several byproducts, including carbon dioxide, manganese dioxide, potassium, chloride, and hydrogen ions are generated and released to the ground water. The byproducts of this reaction are not expected to be a problem since most are either innocuous or will readily react with aquifer material and subsequently stabilize.

It is well documented that $KMnO_4$ has the ability to oxidize chlorinated alkenes in ground water. However, the oxidant is not selective and any compound that can be oxidized that is present in the soil and ground water will consume the $KMnO_4$. It is important to evaluate the site-specific SOD to determine how much of the oxidant will be available to oxidize the TCE. Localized values of the SOD were obtained from evaluations performed by ERM during the remedial investigation in 2003 and during the recent pre-design investigation in 2007. The results of the test on B-Zone soil indicated that the SOD ranges between 0.5 and 1 pounds of $KMnO_4$ per cubic yard of sandy soils and 4 to 10 pounds of $KMnO_4$ per cubic yard of silty soil. For the purposes of this pilot study, we have applied a soil oxidant demand of 0.75 pound per cubic yard for sandy soils and 10 pounds per cubic yard for silty soils. Results of these soil oxidant demand evaluations are included in Appendix A.

A relatively small volume of $KMnO_4$ will be injected as part of this pilot study. Therefore, any migration of $KMnO_4$ from the pilot study injection areas (Figure 2) will be consumed by soil and organic compounds in ground water within a short distance. The subsurface lithology at the site and in the downgradient neighborhood is well documented and an extensive monitoring well network is in place. Therefore, the potential for the $KMnO_4$ to move any significant distance or in an untraceable direction is extremely unlikely.

Long-term $KMnO_4$ injections can potentially cause buildup of manganese dioxide solids on the soil particles, which can potentially reduce the soil permeability over time. However, the mass of $KMnO_4$ to be injected and the resulting mass of precipitated manganese dioxide is low relative to the pore volume being treated. ERM does not anticipate any change in soil permeability within the pilot study area due to the small volume of $KMnO_4$ that will be used during the pilot study.

3.0 CHEMICAL OXIDATION PILOT STUDY ACTIVITIES

The pilot study will focus on two separate areas of the onsite plume. One area is in the vicinity of MW-11B, where some of the highest concentrations of TCE have been detected at the site. This area is immediately adjacent to the primary Hookston Station source area at 199 Mayhew Way. MW-11B and the proposed injection well IP-1 are at the upgradient edge of the B-Zone TCE plume.

The second area that will be studied is along the axis of the TCE plume, near MW-13B. This area also has elevated concentrations of TCE, and represents a convenient onsite location to perform this study based on the absence of significant business operations and the existing monitoring well network that already exists (MW-13B and TW-1).

The implementation of this pilot study consists of several components, as follows:

- Collect baseline ground water samples;
- Inject the $KMnO_4$ solution into two injection points during one injection event;
- Conduct performance ground water monitoring events; and
- Evaluate the ground water monitoring data and incorporate the data evaluation results into the B-Zone Chemical Oxidation Remedial Design.

This section outlines the activities to be performed as part of the chemical oxidation pilot study. The components of this Pilot Study are presented below in order of completion during the test.

3.1 BASELINE GROUND WATER SAMPLING

ERM will collect baseline ground water samples from monitoring wells MW-11B, MW-12B, MW-13B, and test well TW-1 prior to injecting the chemical oxidant. These samples will be used to evaluate baseline ground water conditions prior to introducing the $KMnO_4$ to B-Zone ground water.

The samples will be collected by low-flow purge technique in accordance with the Standard Operating Procedure (SOP) included in Appendix B. The baseline ground water samples will be analyzed for the following:

- Volatile organic compounds (VOCs) by United States Environmental Protection Agency (USEPA) SW-846 Method 8260;
- Potassium, iron, and manganese by USEPA Methods 6010 and 6020 (USEPA SW-846), and chloride by USEPA Method 300.0 (Methods of Chemical Analysis of Waters and Wastes);
- Dissolved chromium by USEPA SW-846 Method 6010;
- General water quality parameters, including dissolved oxygen concentration, reduction/oxidation potential, specific conductivity, turbidity, temperature, and pH; and
- Visual observation for color.

All ground water sample analyses will be performed by a California-certified laboratory, except general water quality parameters and visual color observation, which will be measured in the field during purging activities with an in-line, flow-through cell. All ground water samples submitted for laboratory analyses will be preserved, stored, and shipped in accordance with the SOP provided in Appendix B.

3.2 CHEMICAL OXIDATION INJECTION

The chemical oxidant will be injected in two locations through temporary injection points, IP-1 and IP-2, advanced with a direct-push-technology drill rig. Activities associated with the drilling and injection activities are described below.

3.2.1 Permits

Drilling permits will be obtained from the Contra Costa County Environmental Health Department. Private access agreements will be obtained for activities to be conducted at IP-1. In addition, the principles and procedures described in this workplan will be reviewed by the Water Board for approval prior to performing the injections described below.

3.2.2 Utility Clearance

Prior to commencement of drilling activities, all proposed drilling locations will be marked for underground utility clearance. Underground Services Alert (USA) will be notified no less than 48 hours prior to the start of work. In addition, a private utility locator will be retained to identify underground utilities in the vicinity of the drilling locations.

3.2.3 *Potassium Permanganate Solution*

The chemical oxidant will be injected in two locations at the site, as shown on Figure 2. Injection point IP-1 is located near MW-11B, where TCE has been detected at concentrations up to 24,000 micrograms per liter (µg/L). Injection point IP-2 will be located near MW-13B and TW-1, where TCE concentrations have been reported up to 6,300 µg/L.

An appropriate mass of chemical oxidant must be injected into the subsurface to effectively treat the compounds of concern. A large volume of a dilute concentration solution is anticipated to result in a larger radius of influence during the injections, as compared to a smaller volume of a higher concentration solution that delivers an equal mass of oxidant. This pilot study will involve injecting approximately 2,800 gallons of a 2% $KMnO_4$ solution at IP-1 and approximately 3,500 gallons of a 2% $KMnO_4$ solution at IP-2. These values were calculated using the volume of soil and ground water anticipated to be treated during the pilot study and mass of oxidant required within that volume to treat both the SOD of the soil, as determined by the bench testing described above, and the contaminant mass within the treatment volume. The calculations to determine the oxidant mass and solution volume are presented as Appendix C. The oxidant solution will be injected during one injection event.

The raw $KMnO_4$ product will be obtained from Carus Corporation, and is designed for in situ treatment of ground water and contains very low quantities of impurities relative to products used in industrial applications. Carus Corporation has extensive experience providing oxidant for ground water treatment applications.

3.2.4 *Potassium Permanganate Injection*

The preferred method for injecting a chemical oxidant is typically through closely spaced, vertical, direct-push injection locations. For this pilot study, two injection points, IP-1 and IP-2, will be utilized. IP-1 will be located approximately 10 feet upgradient of MW-11B and IP-2 will be located approximately 15 feet upgradient of TW-1 (Figure 2). The locations of the injection points were selected based on the ground water flow direction, the average B-Zone ground water flow velocity, and access based on current business operations and the presence of underground utilities.

The depth intervals to be treated are based on recent sampling completed as part of the pre-design investigation. Cone penetrometer testing (CPT) and membrane interface probe (MIP) sampling was completed in the vicinity of the proposed injection point locations IP-1 and IP-2. The results of that work are included in Appendix D. Boring CPT-35 was completed at the proposed location of IP-1, and boring CPT-48 was completed at the proposed location of IP-2. Based on the CPT and MIP results, the target depths for treatment will be 38 to 48 feet below ground surface (bgs) at IP-1 and 35 to 55 feet bgs at IP-2. Note that the targeted treatment interval at IP-2 consists of sandy silts from approximately 35 to 45 feet bgs and sands from approximately 45 to 55 feet bgs. Injection point IP-1 consists primarily of sandy silts between 38 and 48 feet bgs.

The temporary injection points will be installed using common direct-push drilling equipment and methods. At the concentration proposed for this pilot study, $KMnO_4$ does not aggressively attack carbon steel tooling like some other oxidants, which is the preferred tooling for this work. Standard, small-diameter, hollow direct-push tooling with an expendable drive tip will be used. The $KMnO_4$ solution will be mixed and injected by Vironex, Inc., a contractor that has specialized equipment for injecting permanganate solutions. The raw $KMnO_4$ product will be shipped directly to Vironex, Inc., and will only be present onsite during the injection program. There will be no storage of $KMnO_4$ product at the site. Vironex will perform the injections using a direct-push rig as summarized below:

- The direct-push rig will advance a drive rod to an appropriate depth within the B-Zone aquifer (approximately 48 feet bgs at IP-1 and approximately 55 feet bgs at IP-2) based on recent CPT/MIP testing that was completed in these areas.
- After reaching the bottom of the borehole, the drive rod will be extracted by approximately 1 foot to release the expendable tip, opening the hollow drive rod.
- The solution will then be pumped into the borehole based on the chemical dosing requirements.
- If the silty units at IP-1 or IP-2 are unable to receive the prescribed dose in a reasonable timeframe, additional injection point(s) will be advanced within 2 to 3 feet of the injection point to facilitate the lateral distribution of the oxidant.
- At the completion of each injection, the boring will be abandoned by grouting from the bottom to the surface with a cement/bentonite slurry. The surface of each borehole will be restored as closely as possible to its original condition. The location will then be marked and surveyed at a later date by a California-licensed land surveyor.

The above procedure may be modified in the field based on site conditions, as necessary. In the event that the borehole is not as receptive to injection as expected, the injection will be suspended for a period of 10 to 15 minutes and then restarted. The total injection volume and location of each borehole will be noted in the field logbook.

3.3 PERFORMANCE MONITORING

ERM will conduct four performance monitoring events following the completion of the injection activities. The timing and objectives of the performance monitoring events are as follows:

Event	Schedule	Objective
1	Conducted 1 day after the injection activities are complete.	• Evaluate the lateral distribution of the chemical oxidant within the subsurface immediately following the injection event. Data collected during this monitoring event will be utilized to select the appropriate lateral spacing for the injection points for the full-scale ISCO remediation program and determine the appropriate volume of chemical oxidant to be injected at each injection point during the full-scale ISCO remediation program.
2	Conducted 2 weeks after the injection event.	• Evaluate chemical concentration trends following one injection treatment, migration of the chemical oxidant within the B-Zone, and to further evaluate the total permanganate demand of the B-Zone.
3	Conducted 4 weeks following injection activities.	
4	Completed 8 weeks after injection event.	

Ground water samples will be collected during the performance monitoring events from a combination of existing monitoring wells, existing test well, and temporary sampling locations, as described in the following sections.

3.3.1 *Performance Monitoring Event #1*

This performance monitoring event will be conducted the day after the chemical oxidant injections are completed to determine the lateral distribution of the chemical oxidant solution within the immediate vicinity of the injection point. The $KMnO_4$ solution that will be injected during the pilot study will have a distinct purple color, which is easily identified when present in ground water. Therefore, ground water samples will only be collected for visual color observation during this performance monitoring event to determine the lateral distribution of the $KMnO_4$ solution around each injection point.

To complete this performance monitoring event, a direct-push sampling rig will be utilized to collect grab ground water samples from temporary sampling points advanced surrounding IP-1 and IP-2. Borings will be advanced across the treated interval to evaluate the distribution of the $KMnO_4$ solution based on visual observations. Initially, borings will be completed downgradient and side-gradient of each injection well at a distance of approximately 5 feet (based on anticipated zone of displacement, see Appendix C). Based on the presence or absence of $KMnO_4$ solution at these locations, additional borings will be completed inward or outward from the injection point until the distribution of the initial injection has been characterized.

3.3.2 *Performance Monitoring Events #2, 3, and 4*

Performance Monitoring Events #2, 3, and 4 will be conducted 2 weeks, 4 weeks, and 8 weeks after the chemical oxidant injections are completed at IP-1 and IP-2.

3.3.2.1 *Treatment Area near IP-1*

To evaluate the performance of the chemical oxidant injection at IP-1, additional grab ground water samples will be collected from temporary sampling points using a direct-push drilling rig between IP-1 and MW-11B. The objective of these events is to determine the migration of the $KMnO_4$ solution and the geochemical changes that result from the injection. The actual locations for these samples cannot be determined at this time, as they will be based on the results of the preceding performance monitoring events. Ground water samples will also be collected from monitoring wells MW-11B and MW-12B during performance monitoring events #2, 3, and 4.

3.3.2.2 *Treatment Area near IP-2*

Similar to the IP-1 study area, additional grab ground water samples will be collected from temporary sampling points using a direct-push drilling rig between IP-2 and TW-1. The actual locations for these samples cannot be determined at this time, as they will be based on the results of the preceding performance monitoring events. Ground water samples will also be collected from monitoring wells TW-1 and MW-13B during performance monitoring events #2, 3, and 4.

3.3.2.3 *Analytical Program*

The analytical program proposed for Performance Monitoring Events #2, 3, and 4 will be the same as the baseline sampling event analytical program, with the following modifications:

- Samples for VOC analysis will not be collected at locations in which the ground water is observed to be pink or purple in color, indicating the $KMnO_4$ solution is present.
- Samples for dissolved chromium analysis will only be collected at one sampling point or monitoring well downgradient of IP-1 and IP-2 during each event.

4.0 DATA EVALUATION AND REPORTING

Following the performance monitoring events and laboratory analysis, the ground water monitoring data collected during the pilot study will be analyzed as a function of time and distance from the injection locations. This information will be used to determine the aerial influence of the injections, aquifer stability, and demand for $KMnO_4$. The results will be utilized to design the full-scale B-Zone chemical oxidation remediation program and will be incorporated into the Remedial Design, which will be submitted to the Water Board by 31 August 2007.

5.0 HEALTH AND SAFETY PLAN ADDENDUM

Activities described in this workplan will be performed in accordance with the current site-specific *Health and Safety Plan* (HASP), which is included within the *Phase I Remedial Investigation Sampling and Analysis Plan* (ERM, 2000). The procedures described by the plan will be implemented and enforced by a health and safety representative during site work. Compliance with the HASP will be required of all persons who enter restricted areas for the project.

In addition to the existing HASP for the site, ERM has developed this activity-specific HASP Addendum that will address specific issues associated with the oxidant injection component of this pilot study. Key components of the HASP are described below.

5.1 PURPOSE OF THE HASP ADDENDUM

- Assign site personnel health and safety responsibilities;
- Establish process safety requirements for all equipment, including hazards associated with the use of strong oxidizers, flammable materials, and other hazards;
- Prescribe mandatory operating procedures;
- Establish personal protective equipment requirements for work activities;
- Establish chemical handling and disposal procedures;
- Establish emergency response procedures; and
- Provide information on the health and physical hazards of on-site activities.

The HASP Addendum complies with all federal Occupational Safety and Health Administration (OSHA) regulations, as applicable and appropriate. In addition to the site-specific HASP, the following safety information regarding working with permanganate will be disseminated and personal protection measures implemented.

5.2 HAZARDS AND PROCEDURES FOR OXIDANT INJECTION

This section describes chemical hazards associated with the use of $KMnO_4$ that may be encountered during implementation of the work described in this workplan.

5.2.1 Chemical Description and Symptoms of Exposure

$KMnO_4$ is a nonflammable but highly oxidizing solid. It is dark purple and odorless. $KMnO_4$ in free-flowing granular form will be transported to the site, mixed with water to form a dilute solution of approximately 2% by weight, and injected into the ground water through direct-push injection boreholes.

Routes of exposure are ingestion, skin and/or eye contact, and inhalation of $KMnO_4$ dust crystals. Ingestion of concentrations up to 1 percent causes burning of the throat, nausea, vomiting, and abdominal pain; 2 to 3 percent causes anemia and swelling of the throat with possible suffocation; and 4 to 5 percent may cause kidney damage.

Dry crystals and concentrated solutions are strong oxidizers causing redness, pain, severe burns, brown stains in the contact area, and possible hardening of outer skin layer. Diluted solutions are only mildly irritating to the skin. Eye contact with crystals (dust) and concentrated solutions causes severe irritation, redness, blurred vision, and can cause severe damage, possibly permanent. Exposure to $KMnO_4$ can cause lung irritation and central nervous system damage. The current federal OSHA short-term exposure limit for $KMnO_4$ is listed as 5 milligrams per cubic meter of air for manganese compounds.

5.2.2 Level C Protection (Modified for Activities Involving $KMnO_4$)

Exposure to $KMnO_4$ will be prevented through the proper use of personal protective equipment, including gloves, face and eye protection, and coveralls. Special Level C protection is required for activities where $KMnO_4$ is being handled and used in solid or concentrated form. This special Level C protection consists of Level D protection, plus the following:

- Half-face respirator equipped with combination organic vapor/HEPA filter cartridges;
- Full-face shields;

- Chemical resistant clothing (i.e., polycoated Tyvek, or Saranex), consisting of one-piece suits with attached hoods, booties, and elastic wrist bands; and
- Outer nitrile gloves and inner latex surgical gloves.

When only dilute $KMnO_4$ solutions (5 percent or less) are present, no respiratory protection is required.

If chemicals are splashed into the eyes, a 15-minute eye wash will be performed using fresh water available at the site. Any dermal exposures will be immediately washed using the same running fresh water source.

5.2.3 *Procedures for Working with $KMnO_4$*

Management practices will be implemented during use of $KMnO_4$ that will reduce potential exposure, including:

- Keeping $KMnO_4$ containers sealed until immediately prior to use;
- Dispensing the granular $KMnO_4$ with as little agitation as possible;
- Protecting the granular $KMnO_4$ from wind; and
- Frequently checking tightness of fittings on pressurized injection equipment and piping.

In addition to presenting a health hazard, $KMnO_4$ in the solid form used for this work presents a reactivity hazard if exposed to certain incompatible materials. Materials incompatible with $KMnO_4$ likely to be present in the same location during this work would be gasoline or diesel automobile or equipment fuel, ethylene glycol automotive antifreeze, and hydraulic fluid. If exposed to gasoline or diesel fuel or other organic fluids such as hydraulic fluid, motor oil, or greases, solid $KMnO_4$ can potentially initiate combustion of those materials. If exposed to ethylene glycol antifreeze, the incompatibility of the solid $KMnO_4$ can cause an exothermic reaction. In addition, if solid $KMnO_4$ is present near an existing fire or other heat source that raises the temperature to above approximately 300 degrees F, the $KMnO_4$ can spontaneously decompose. This decomposition releases oxygen, which will support the existing combustion or potentially initiate combustion. To prevent the reaction of stored or used $KMnO_4$, the following procedures and practices will be followed:

- Maintain a current material safety data sheet (MSDS) with the product at all times;

- Require personnel responsible for transporting the $KMnO_4$ to review the MSDS and become familiar with reactivity data;
- Transport $KMnO_4$ only in closed and sealed containers to prevent or reduce spillage on bumpy roads or during a traffic accident;
- Do not store or use $KMnO_4$ near fuels; and
- Do not store or use $KMnO_4$ near a heat source.

The above hazards associated with potassium permanganate are primarily associated with the pure, solid form prior to dilution and injection. The dilute solution of $KMnO_4$ to be injected is an oxidant, but does not exhibit many of the dangers associated with the pure form. However, the same procedures and practices used to prevent exposure to or reaction of the solid form will be used during preparation and use of the dilute solution of $KMnO_4$.

6.0 SCHEDULE

The following is a timeline for completing the pilot study, assuming that this workplan is approved by the Water Board by 16 April 2007:

- Utility Clearance and Permitting – completed by 30 April 2007.
- Baseline ground water sampling – completed the week of 30 April 2007.
- Chemical oxidation injections – completed 3 May 2007.
- Performance monitoring events – completed 4 May, 17 May, and 31 May, and 28 June 2007.
- Results of the Pilot Study will be documented in the B-Zone Chemical Oxidation Remedial Design, which is due to the Water Board on 31 August 2007.

The full-scale implementation of ISCO remediation program will occur following Water Board approval of the Remedial Design.

Figures

Project No. 8219.10

Date: 11/13/00

Drawn By: J. Estrada

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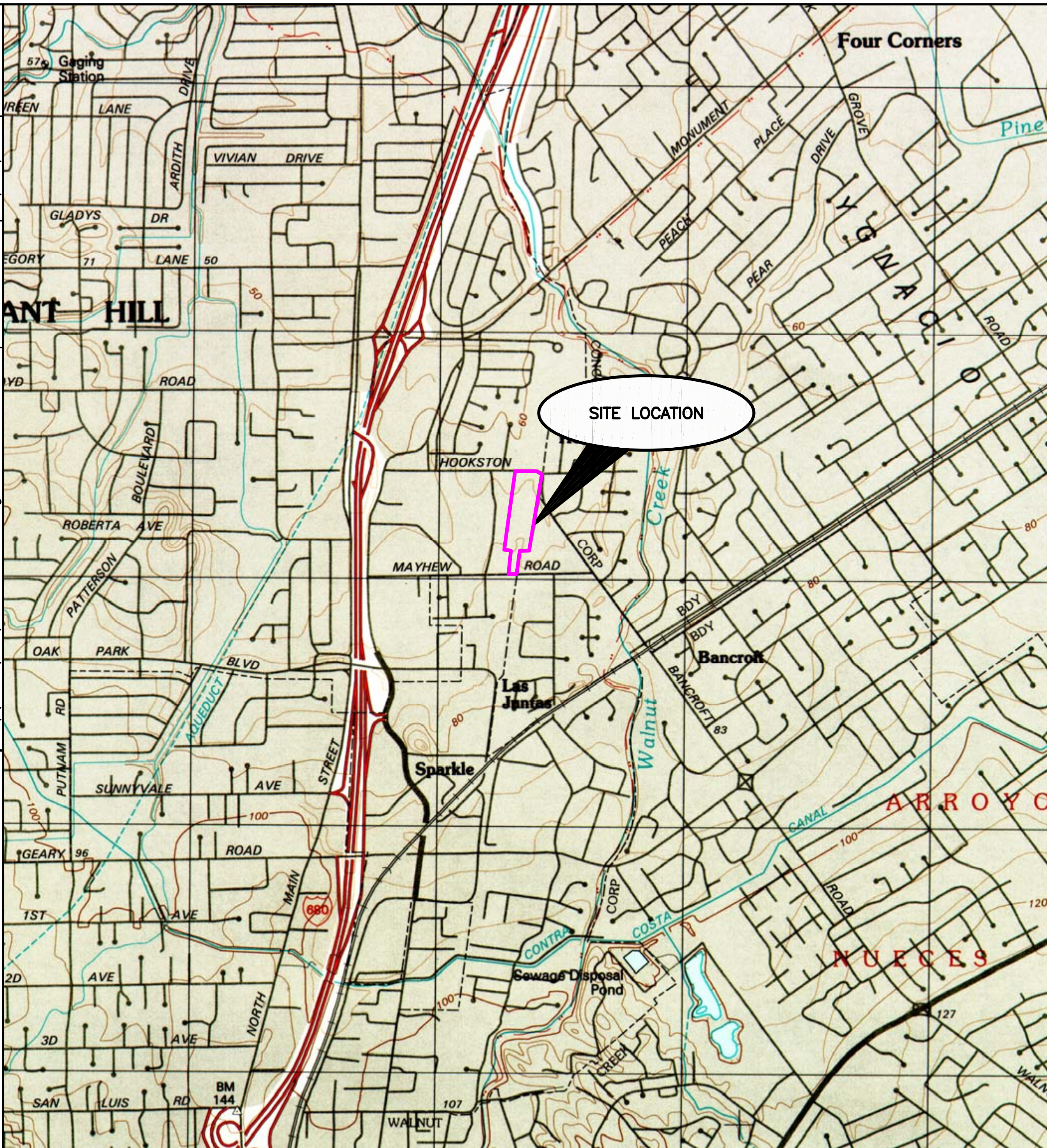

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References:
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Dated: 1993

Figure 1

Site Location Map
Hookston Station Project
Pleasant Hill, California

ERM 02/00

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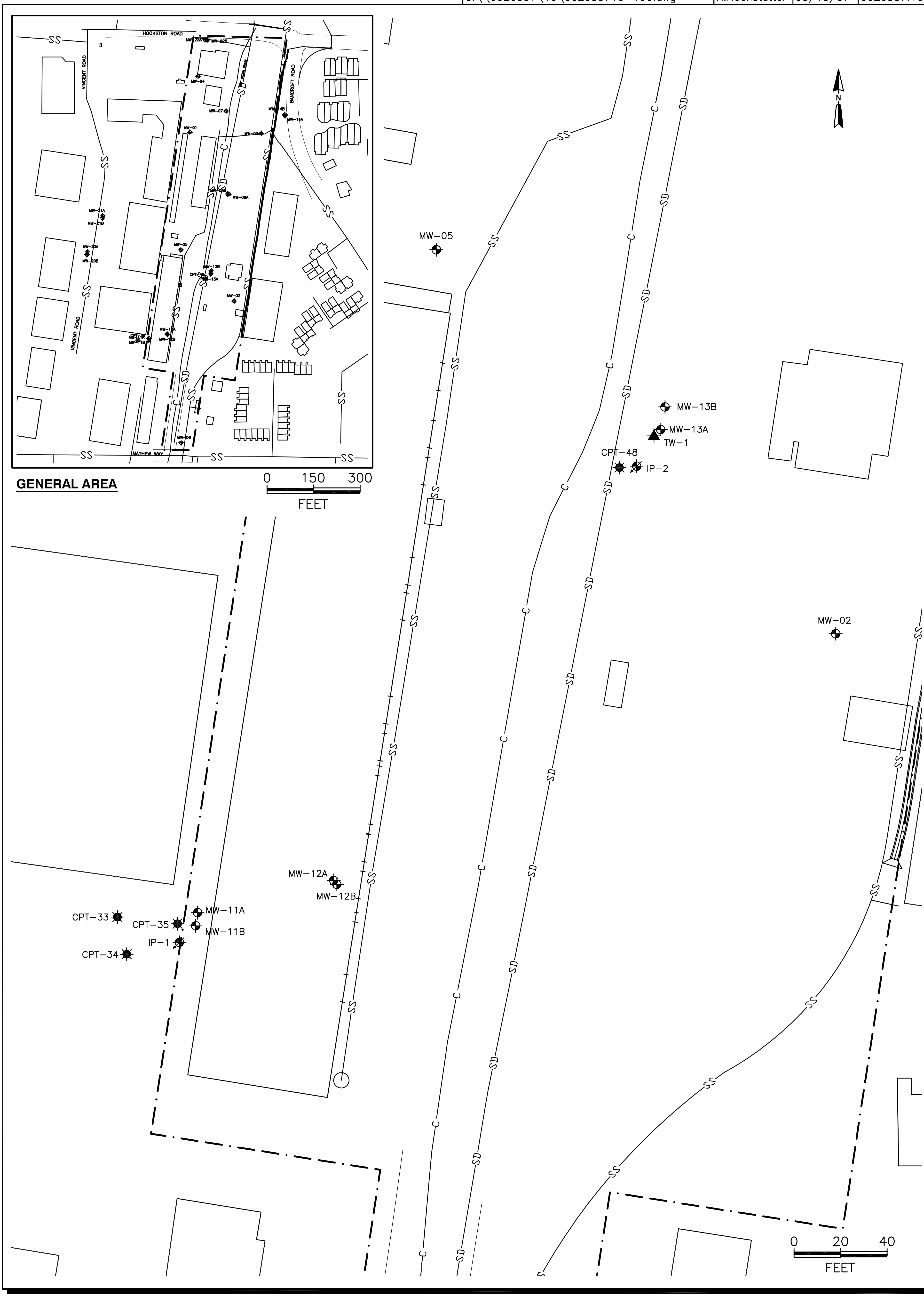

LEGEND:

- EXISTING MONITORING WELL
- EXISTING TEST WELL
- PROPOSED CHEMICAL OXIDATION INJECTION POINT
- CPT GROUNDWATER SAMPLE LOCATION
- HOOKSTON STATION PARCEL PROPERTY BOUNDARY
- —C— UNDERGROUND FIBER OPTIC (COMM.) LINE
- —SS— SANITARY SEWER LINE
- —SD— STORM DRAIN LINE

Figure 2

Proposed Pilot Study Locations
Hookston Station Project
Union Pacific Railroad
Pleasant Hill, California

ERM 03/07

Appendix A
Chemical Oxidation Treatability Study

Memorandum

Environmental Resources Management

1777 Botelho Drive
Suite 260
Walnut Creek, CA 94596
(925) 946-0455
(925) 946-9968 (fax)

To: Project File

From: Arun Chemburkar

Date: 31 May 2006

Subject: Chemical Oxidation Treatability Study for UPRR/Helix, Pleasant Hill, California

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This memorandum is intended to accompany and summarize the 22 December 2003 letter report *Chemical Oxidation Treatability Study for UPRR/Helix, Pleasant Hill, California* produced by ERM's Remediation Technology Center (RTC) in Lawrenceville, New Jersey.

To evaluate the effectiveness of chemical oxidation using permanganate and persulfate in treating site soils, RTC analyzed two composite samples (designated "shallow" and "deep"), in late 2003. Specifically the bench-scale tests evaluated the soil permanganate demand and the amount of persulfate consumed by the samples. A sample of each of the composites was also sent to Severn Trent Laboratories in West Sacramento, California for total organic carbon and volatile organic compound analyses.

The shallow soil composite, collected from depths representative of the A-Zone aquifer, exhibited a "moderate" total permanganate demand (4 to 7 pounds per cubic yard [lb/yd^3]). The shallow soil composite consumed only 15 to 17%, (5X and 20X concentrations, respectively), of the initial persulfate concentrations during the 14-day test. This relates to a persulfate demand of 6 to 27 lb/yd^3.

The deep soil composite, collected from depths representative of the B-Zone aquifer, exhibited a "low" total permanganate demand, (0.5 to 1 lb/yd^3). As with the shallow sample, the deep soil composite consumed only 15 to 17% of the initial persulfate concentrations during the 14-day test. This consumption rate relates to a persulfate demand of 6 to 28 lb/yd^3.

Based on the significantly greater amount necessary to treat a given soil volume and the increased cost per pound of persulfate, permanganate is the preferred oxidant for implementing a chemical oxidation remediation for ground water treatment at the site.

Environmental Resources Management

250 Phillips Blvd, Suite 280
Ewing New Jersey 08618
609-895-0050
609-895-0111 (fax)

22 December 2003

Reference: 0011397

Mr. Arun Chemburkar
ERM-West, Inc.
1777 Botelho Drive, Suite 260
Walnut Creek, CA 94596

Re: Chemical Oxidation Treatability Study for UPRR/Helix, Pleasant Hill, California

Dear Mr. Chemburkar,

This letter report presents the findings of the recent chemical oxidation treatability study performed on VOC-contaminated soils collected from the Hookston Station Site in Pleasant Hill, California. The study was designed to evaluate the total soil permanganate demand and the amount of persulfate consumed by each of two soil samples.

SUPPLY OF SITE SOILS

Site soil samples arrived at ERM's Remediation Technology Center (RTC) in Lawrenceville, New Jersey on 3 October 2003. Five soil samples arrived in good condition, were logged in, and were designated as follows:

- 08190-01: B-68-17.5-18.5;
- 08190-02: MW-13B-23;
- 08190-03: B-68-53;
- 08190-04: MW-12B-18.5; and
- 08190-05: MW-12B-53.

All samples were stored refrigerated until used.

TREATABILITY STUDY

The study consisted of three phases of work as described in the sections that follow.

Phase I: Initial Characterization

The five soil samples were combined into two separate composites, designated as "shallow" and "deep." The shallow composite was made up from B-68-17.5-18.5, MW-13B-23, and MW-12B-18.5. The deep composite was made up from B-68-53 and MW-12B-53.

Each of the composite soils was constructed by adding the individual soils to a large bucket, mixing them together by hand until they appeared homogeneous, and then removing any large debris that was present. A sample from each of the composite soils was submitted to Severn Trent Laboratories (STL) in West Sacramento, California, for Total Organic Carbon (TOC) and VOC analyses. The results of these tests are shown in Table 1.

The VOC concentrations were needed to determine the stoichiometric demand of the chlorinated solvents present in each soil composite for persulfate treatment. Because no VOCs were detected in either composite soil, an "assumed" total VOC concentration of 75 mg/kg was used to calculate the mass of persulfate to add in the Persulfate Soil Consumption Test. The ERM-West project manager discussed and approved this assumed total VOC concentration.

Phase II: Total Soil Permanganate Demand

In addition to reacting with many hazardous chemicals, permanganate will react with many organic and inorganic materials naturally present in site soils. If the concentrations of these non-target oxidizable materials are very high, large amounts of oxidant will be required for field treatment, resulting in high full-scale implementation costs. The soil demand test is designed to evaluate the oxidant demand exerted by site soils.

The test was individually performed on each composite soil by adding 25 grams of wet-weight processed soil to each of ten 50-ml centrifuge tubes. Increasing volumes (20 µL to 10 mL) of a stock 5% potassium permanganate solution and distilled water were added to each tube to bring the total liquid volume in each tube to approximately 40 mL. The ten tubes made up a concentration series ranging from 1 to 500 mg of potassium permanganate per tube; each tube in the series contained twice the permanganate concentration of the preceding tube. In addition, a "Control" tube was constructed containing only soil and distilled water. All tubes were incubated at room temperature (approximately 20°C) in the laboratory.

All centrifuge tubes were manually mixed over the 15-day reaction period (18 November to 3 December 2003). At that time, the color of the liquid in each tube was visually determined and recorded. For each composite, the pH and ORP of the tubes which bracketed the tube with the lowest residual concentration of permanganate were also measured and recorded.

Solutions containing residual permanganate were pink to purple in color, while solutions in which the starting mass of permanganate had been essentially depleted were colorless. The actual total soil permanganate demand concentration lies between the tube with highest concentration of exhausted permanganate and the tube with the lowest concentration of residual permanganate. The results of the permanganate demand tests for the composite soils are shown in Table 2.

Shallow Composite: The soil permanganate demand is between 1.4 and 2.6 g/kg. Based on comparisons with similar oxidant demand tests, this soil would be considered to exhibit a "moderate" total permanganate demand. This result is consistent with the relatively moderate TOC concentration of the processed soil.

Scaled up, the permanganate demand would theoretically correspond to the need for approximately 4 to 7 pounds of permanganate per cubic yard of soil treated. These calculations were made assuming a soil porosity of 30% and a bulk density of 2,700 lb/yd^3.

Deep Composite: The soil permanganate demand is between 0.17 and 0.35 g/kg. Based on comparisons with similar oxidant demand tests, this soil would be considered to exhibit a "low" total permanganate demand. This result is consistent with the low TOC concentration of the processed soil.

Scaled up, the permanganate demand would theoretically correspond to the need for approximately 0.5 to 1 pound of permanganate per cubic yard of soil treated. These calculations were made assuming a soil porosity of 30% and a bulk density of 2,700 lb/yd^3.

Phase III: Persulfate Soil Consumption Test

The test was individually performed on each of the two composites by adding 200 g of wet-weight processed soil to each of three 500-mL centrifuge bottles. The Control bottle then received 300 mL of distilled water, was sealed, and shaken by hand to mix. One reaction bottle then received 3 g of sodium persulfate to achieve an oxidant mass equal to five times the stoichiometric demand of the "assumed concentration" of contaminants. The second reaction bottle received 12 g of sodium persulfate to achieve a 20 times excess mass of oxidant. Each of these two reaction bottles then received an iron catalyst at 100 mg/Kg. The bottles were then filled with 300 mL of distilled water, capped, and shaken by hand to mix.

The six bottles were placed on a shaker table to mix over the 14-day reaction period (19 November to 3 December 2003). After seven days of treatment (26 November 2003), the bottles were removed from the shaker table, and the slurries were analyzed for pH, ORP, and residual persulfate. The bottles were then returned to the shaker table to complete the reaction period. On Day 14 (03 December 2003), the six bottles were again removed from the shaker table and the slurries were analyzed for pH, ORP, and residual persulfate. Results from this test are shown in Table 3.

Shallow Composite: After a 14-day reaction period, residual persulfate was detected in both the 5X and 20X excess reaction samples. The percent loss of the 5X excess reaction sample was 14.94%, and the 20X excess reaction showed a 16.52% loss. On a mass consumed per mass of soil treated basis, the 5X composite exhibited a total demand of approximately 2 grams of persulfate per kilogram of wet-weight soil, while the 20X composite exhibited a total demand of approximately 10 grams per kilogram.

These rates of persulfate loss were deemed to be relatively "low," and indicate that a significant concentration of residual persulfate would be expected to exist in site soils after a contact time of two weeks. The residual persulfate would be available for continued chemical oxidation of such soils and/or provide oxidation potential as the oxidant is diluted and moves down gradient with the groundwater flow.

Deep Composite: After a 14-day reaction period, residual persulfate was detected in both the 5X and 20X excess reaction samples. The percent loss of the 5X excess reaction sample was 14.94%, and the 20X excess reaction showed a 17.31% loss. On a mass consumed per mass of soil treated basis, the 5X composite exhibited a total demand of approximately 2 grams of persulfate per kilogram of wet-weight soil, while the 20X composite exhibited a total demand of approximately 10.5 grams per kilogram.

These rates of persulfate loss were deemed to be relatively "low," and indicate that a significant concentration of residual persulfate would be expected to exist in site soils after a contact time of two weeks. The residual persulfate would be available for continued chemical oxidation of such soils and/or provide oxidation potential as the oxidant is diluted and moves down gradient with the groundwater flow.

CONCLUSIONS

The following conclusions can be drawn from the results of this treatability study:

- The "Shallow" soil composite exhibited a total permanganate demand of 1.4 to 2.6 g/kg, a range considered to be "moderate" based on the results of many such tests;
- The "Shallow" soil composite consumed a relatively low percentage of the starting persulfate concentration during the two week test (15 to 17%, respectively, with a 5X and 20X stoichiometric excess). The 5X and 20X composite soils exhibited a total demand of approximately 2 and 10 grams of persulfate per kilogram of wet-weight soil, respectively;
- The "Deep" soil composite exhibited a total permanganate demand of 0.17 to 0.35 g/kg, a range considered to be "low;" and
- The "Deep" soil composite consumed a relatively low percentage of the starting persulfate concentration during the two week test (15 to 17%, respectively, with a 5X and 20X stoichiometric excess). The 5X and 20X composite soils exhibited a total demand of approximately 2 and 10.5 grams of persulfate per kilogram of wet-weight soil, respectively

The representativeness of the soil samples supplied for use in the demand tests should be carefully considered when interpreting the laboratory results. This is especially true when composite, rather than discrete samples are tested. Results from soils not "typical" of those at the site to be treated can result in significant under or over statement of the true soil oxidant demands. Field pilot testing can be used to verify the bench-scale results and to provide data valid for process scale-up.

Since both permanganate and persulfate are successful in oxidizing chloroethenes, the choice between the oxidants typically centers around two key issues: (1) economics of use, and (2) ease of implementation. For economics of use, the total oxidant demand numbers can be compared to provide an initial evaluation of cost-effectiveness. For ease of implementation, permanganate treatment is in general superior to persulfate oxidation because permanganate solutions are chemically stable, react without the need for catalysts, and the pink to purple color of these solutions is helpful in easily determining whether the oxidant is present or not.

The shallow composite soils exhibited an extrapolated total permanganate demand of 4 to 7 pounds of permanganate per cubic yard of soil treated, while the total persulfate demand ranged from approximately 6 pounds of persulfate per cubic yard at 5X stoichiometry to 27 pounds of persulfate per cubic yard at 20X stoichiometry. Assuming that these demand numbers are accurate, permanganate treatment is cheaper than persulfate treatment on chemical cost per cubic yard of treated soil basis.

The deep composite soils exhibited an extrapolated total permanganate demand of only 0.5 to 1 pound of permanganate per cubic yard of soil treated, while the total persulfate demand ranged from approximately 6 pounds of persulfate per cubic yard at 5X stoichiometry to 28 pounds of persulfate per cubic yard at 20X stoichiometry. Assuming that these demand numbers are accurate, permanganate treatment is cheaper than persulfate treatment on chemical cost per cubic yard of treated soil basis.

In addition to the favorable reagent cost, permanganate treatment is both simpler to implement and more likely to behave in a predictable manner in the field.

Should you have any questions about the study or need additional information, please feel free to contact me at 609-895-0050.

Sincerely,

Richard A. Brown

Richard A. Brown

Table 1. Initial Characterization Results
Hookston Station
Pleasant Hill, CA
16-Dec-03

1-A. Shallow Composite

Analyte	Concentration (mg/kg)
Total Organic Carbon (TOC)	1,720
VOCs	ND*

*Not detected

1-B. Deep Composite

Analyte	Concentration (mg/kg)
Total Organic Carbon (TOC)	455
VOCs	ND*

*Not detected

Table 2. Total Soil Permanganate Demand
Hookston Station
Pleasant Hill, CA
16-Dec-03

2-A. Shallow Composite

Theoretical Permanganate Load (mg/kg of wet-weight soil)	Actual Permanganate Load (mg/kg of wet-weight soil)	Observed Supernatent Color	Observed ORP (mV)	Observed pH	Permanganate Demand (g/kg of wet weight soil)		Permanganate Demand (lbs/yd^3 soil)*	
20,000	21,054	Purple	NA**	NA	<	21	<	57
10,000	10,523	Purple	NA	NA	<	11	<	28
5,000	5,266	Purple	659.2	7.5	<	5	<	14
2,500	2,570	Pink	582.5	7.9	<	2.6	<	6.9
1,250	1,397	Clear	534.3	8.6	>	1.4	>	3.8
625	714	Clear	NA	NA	>	0.71	>	1.9
313	351	Clear	NA	NA	>	0.35	>	0.95
156	157	Clear	NA	NA	>	0.16	>	0.42
78	81	Clear	NA	NA	>	0.081	>	0.22
39	52	Clear	NA	NA	>	0.052	>	0.14

*Assumes a 30% porosity and a soil bulk density of 100 lbs/ft^3
**NA = Not Analyzed

2-B. Deep Composite

Theoretical Permanganate Load (mg/kg of wet-weight soil)	Actual Permanganate Load (mg/kg of wet-weight soil)	Observed Supernatent Color	Observed ORP (mV)	Observed pH	Permanganate Demand (g/kg of wet weight soil)		Permanganate Demand (lbs/yd^3 soil)*	
20,000	20,974	Purple	NA**	NA	<	21	<	57
10,000	10,539	Purple	NA	NA	<	11	<	28
5,000	5,261	Purple	NA	NA	<	5	<	14
2,500	2,583	Purple	NA	NA	<	2.6	<	7.0
1,250	1,402	Purple	627.5	7.9	<	1.4	<	3.8
625	695	Purple	586.1	8.3	<	0.70	<	1.9
313	354	Lt. Pink	542.3	8.5	<	0.35	<	0.96
156	165	Clear	598.5	8.8	>	0.17	>	0.45
78	77	Clear	NA	NA	>	0.077	>	0.21
39	40	Clear	NA	NA	>	0.040	>	0.11

*Assumes a 30% porosity and a soil bulk density of 100 lbs/ft^3
**NA = Not Analyzed

Table 3. Persulfate Soil Consumption Test
Hookston Station
Pleasant Hill, CA
16-Dec-03

3-A. "Time = 7 Days" Results

Sample	pH	ORP	Initial Oxidant (mg/L)	Residual Oxidant (mg/L)	Percent Loss	Persulfate Demand (g/kg)*	Persulfate Demand (lb/yd^3 soil)**
Shallow Composite 5X	7.4	602.1	10,000	8,821	11.8	1.8	4.8
Deep Composite 5X	7.6	611.3	10,000	8,506	14.9	2.2	6.1
Shallow Composite 20X	7.2	691.7	40,000	33,392	16.5	9.9	26.8
Deep Composite 20X	7.0	690.4	40,000	34,337	14.2	8.5	22.9

*Wet-weight soil
**Assumes a 30% porosity and a soil bulk density of 100 lbs/ft^3

3-B. "Time = 14 Days" Results

Sample	pH	ORP	Initial Oxidant (mg/L)	Residual Oxidant (mg/L)	Percent Loss	Persulfate Demand (g/kg)*	Persulfate Demand (lb/yd^3 soil)**
Shallow Composite 5X	7.5	613.0	10,000	8,506	14.9	2.2	6.1
Deep Composite 5X	7.5	642.4	10,000	8,506	14.9	2.2	6.1
Shallow Composite 20X	7.2	652.1	40,000	33,392	16.5	9.9	26.8
Deep Composite 20X	7.0	666.9	40,000	33,077	17.3	10.4	28.0

*Wet-weight soil
**Assumes a 30% porosity and a soil bulk density of 100 lbs/ft^3

CARUS CORPORATION
Technology and Quality
Remediation Report

8 March 2007

Customer: Environmental Resources Management
1777 Botelho Drive, Suite 260
Walnut Creek, CA 94596

Cc: M. Dingens
K. Frasco
B. Veronda
P. Vella

Attention: Brian Bjorklund
Doug Moberg

From: E. Vlastnik

Keywords: Permanganate
Remediation
Soil

TECH # 10440

Subject: RemOx® S ISCO Reagent Soil Oxidant Demand

Summary
The permanganate soil oxidant demand (PSOD) for the low permanganate dose at 48 hours was determined to be 2.2 g/kg. The PSOD for the medium permanganate dose at 48 hours was determined to be 3.6 g/kg. The PSOD for the high permanganate dose at 48 hours was determined to be 3.8 g/kg. These values are calculated on a weight as potassium permanganate ($KMnO_4$) per dry weight of soil.

Background
One soil sample was received from Environmental Resources Management from the Hookston Station project (Project # 0020557.22) on March 2, 2007. The soil sample was identified as CPT-34-38. The sample was analyzed for a permanganate soil oxidant demand. The measurement of the permanganate soil oxidant demand is used to estimate the concentration of permanganate that will be consumed by the natural reducing agents as well as the contaminants of concern in the soil during a given time period.

Experimental
To determine the PSOD, a reaction vessel for each sample was filled with 30 grams of the soil. Large rocks (>5 grams) were excluded from the analysis. A total volume of 60 mLs of deionized water and concentrated permanganate dosing solution were added for a 1:2 soil to added water ratio. The initial permanganate concentrations were 3.3 g/kg (low dose), 16.4 g/kg (medium dose), and 32.9 g/kg (high dose) on a dry soil basis. The reaction vessels were inverted twice per day during the 48-hour reaction time. Residual permanganate (MnO_4^-) was determined at 48 hours. The moisture content for each soil sample was determined using ASTM Method D 2216-98 and the demands were calculated on a dry weight basis.

Results
The permanganate demand is the amount of permanganate consumed in a given amount of time. It should be noted that in a soil or groundwater sample, the oxidation of any compound by permanganate is dependent on the initial dose of permanganate and the reaction time available. As the permanganate dose is increased, the reaction rate and oxidant consumption may also

increase. Some compounds that are not typically oxidized by permanganate under low doses can become reactive with permanganate at higher concentrations. Therefore, increasing the permanganate dose to extreme excess could be disadvantageous to a remediation project (e.g., inefficient chemical usage, higher costs, etc.).

The 48-hour PSOD results of the soil for the low, medium, and high oxidant doses can be seen in Table 1 (on a dry soil basis).

Table 1: 48-Hour PSOD* for the Low, Medium, and High Permanganate Doses

Sample ID Soil	Low Dose (g/kg)	Medium Dose (g/kg)	High Dose (g/kg)	Soil Moisture (%)
CPT-34-38	2.2	3.6	3.8	19.73

* All demands were calculated on a dry weight basis. To convert the demand results from a dry basis to an as received basis, multiply the dry value by 1 minus the moisture. For example, the demand from the high dose is 3.8 g/kg (dry) x (1-0.1973) = 3.1 g/kg (as received).

Conclusions

For this application the amount of permanganate needed will be dependent on the reaction time allowed. The sample had a low soil demand with a 48-hour permanganate demand value of 3.8 g/kg for the high permanganate dose at 48 hours. Generally, remediation sites with a soil/site groundwater demand of less than 35.0 g/kg at 48 hours for the high permanganate dose are favorable for in-situ chemical oxidation with permanganate (see Table 2 for additional information).

Table 2: Correlation of Soil Oxidant Demand Results*

PSOD (g/kg)	Rank	Comment
<15	Low	ISCO with MnO_4^- is recommended. PSOD contribution to MnO_4^- demand is low.
15-35	Moderate	ISCO with MnO_4^- is recommended.
35-50	Moderately High	ISCO with MnO_4^- is recommended but PSOD will contribute significantly to MnO_4^- demand. Pilot testing may help define these demands.
>50	High	Pilot testing is highly recommended to determine effective PSOD at the site.

*Dry Weight Basis

Appendix B
Standard Operating Procedures for Low-Flow Ground Water Sampling

TABLE OF CONTENTS

LIST OF TABLES

1.0 PURPOSE AND SCOPE

The purpose of this document is to define the standard operating procedure (SOP) for collection of ground water samples by low-flow purge technique at the Hookston Station site in Pleasant Hill, California (site). The ultimate goal of the sampling program is to obtain samples that meet acceptable standards of accuracy, precision, comparability, representativeness, and completeness. All steps that could affect tracking, documentation, or integrity of samples are explained in sufficient detail to allow all sampling personnel to collect samples that are reliable and consistent.

This SOP describes equipment, field procedures, sample containers, decontamination, documentation, storage, holding times, and field quality assurance/quality control (QA/QC) procedures necessary to collect ground water samples from monitoring wells and temporary sampling points by low-flow purge technique.

This plan is to be strictly followed when low-flow sampling is the specified sample collection method, and any modification to the procedure shall be approved by the Project Manager (PM) in advance.

2.0 RESPONSIBILITIES AND QUALIFICATIONS

The PM is responsible for assigning project staff to conduct sampling activities at the site. The PM also ensures that all project personnel follow this and any other appropriate SOPs.

The project staff assigned to the ground water sampling task is responsible for completing all tasks according to this and other appropriate procedures. All staff members are responsible for reporting deviations from the procedure or nonconformance to the PM or Project QA/QC Officer.

Only qualified personnel shall be allowed to perform ground water sampling. At a minimum, ERM employees qualified to perform ground water sampling are required to:

- Read this SOP;
- Indicate to the PM that they understand all procedures contained in this SOP;
- Have completed the OSHA 40-hour training course and/or 8-hour refresher course, as appropriate; and
- Have ground water sampling experience generally consistent with the procedures described in this SOP.

3.0 SAMPLE COLLECTION PROCEDURES

3.1 EQUIPMENT LIST

Sample bottles will be obtained from the analytical laboratory for the requested sample analyses. Extra sample containers will be obtained in case of breakage or other problems. Trip blanks will also be obtained from the analytical laboratory.

Typical equipment list for low-flow purge technique sampling:

- Personal protective equipment, including nitrile or powderless surgical gloves and safety glasses;
- Photoionization detector (PID) or flame ionization detector (FID);
- Water level probe;
- Disposable high-density polyethylene (HDPE) tubing and silicon tubing;
- Pumps;
    - Peristaltic pump
    - Bladder pump
- Water quality meter equipped with probes for measuring pH, specific conductivity, and temperature;
- Additional probes for measuring oxidation-reduction potential, dissolved oxygen, and turbidity may also be utilized;
- In-line flow-through cell;
- Ground Water Sample Collection Data Forms;
- Data recording sheets;
- Field notebook;
- Chain-of-Custody (COC) forms;
- Labels;
- Appropriate sample containers;
- Self-sealing plastic bags;
- Cooler;
- Ice or frozen ice packs;

- Spray bottle for deionized water;
- Deionized water; and
- 55-gallon drums or other type of portable storage container.

Equipment used during decontamination:

- Alconox detergent (or equivalent);
- Deionized water;
- Containers, brushes, paper towels, plastic sheeting; and
- Personal protective equipment, including nitrile or powderless surgical gloves and safety glasses.

3.2 SAMPLING PROCEDURE

This section describes the sequence of events to be followed for well purging and sample collection for the low-flow purge sampling technique.

3.2.1 Equipment Decontamination

Before any purging or sampling activities begin at a well, all non-disposable equipment shall be decontaminated. Details of decontamination procedures are given in Section 5.0.

3.2.2 Low-Flow Purging

Static water levels shall be measured for each well immediately before well purging. Water levels will be measured following the procedures described in SOP #6 (provided in the *Phase I Remedial Investigation Sampling and Analysis Plan, Hookston Station Site, Pleasant Hill, California* [ERM, December 2000]. As specified in SOP #6, the procedure shall be accomplished with a decontaminated electronic measuring probe. Water levels will be measured from the elevation reference point marked on the PVC well casing. The measuring process will be repeated until consecutive water level measurements agree to within 0.01 foot. If floating product is historically known to occur in a well or if there is reason to believe there will be floating product in a new well, an interface probe will be used to measure the depth to water and the thickness of the floating material.

Low-flow purging and sampling methods will be used to obtain representative groundwater samples while minimizing the amount of purge water generated.

Monitoring wells will be purged and sampled according to the following field protocol:

1. Note well condition and any unusual conditions of the area immediately surrounding the well.
2. In unpaved areas, place a clean plastic sheet around the well to prevent surface soils from coming in contact with purging and sampling equipment if no dedicated pump system is present in well.
3. Remove well cover and unlock cap.
4. If necessary, evacuate any standing water within well box prior to removing inner well caps.
5. When inner well caps are removed, perform head space analysis using a PID or FID.
6. Measure and record depth to static water level from measuring point on PVC inner well casing. Repeat the measurement process until values agree within 0.01 foot. Indicate time of measurement.
7. Record total depth of well (measured during water level measurement process).
8. Attach a fresh length of disposable polyethylene (or equivalent) tubing to the outlet of the decontaminated pump. If sampling for natural attenuation parameters, use a peristaltic pump or a bladder pump with no metal parts. If using a bladder pump, lower the pump slowly into the well to minimize the mixing of casing water and the suspension of any silt at the bottom of the well. Place the pump near the middle or slightly above the middle of the screened interval. If using a peristaltic pump, lower the tubing into the well such that the tubing intake is placed within the well screen interval. (Note: these initial steps are only necessary if using a non-dedicated pump.)
9. Connect the discharge end of the tube into the in-line flow-through cell. Connect a second piece of polyethylene tubing from the in-line flow-through cell discharge to a bucket or other receptacle for collecting purge water.
10. Purge at 100 to 500 milliliters per minute; the goal is to minimize draw-down in the well (ideally less than 10 centimeters draw-down). Measure the depth to water to ensure the draw-down within the well does not exceed 10 centimeters.
11. To minimize delays in field parameter stabilization and potential bias in analytical testing results, any vents or other potential sources of air bubbles in the pump discharge tubing or in-line flow-through cell should be identified and sealed off (or otherwise isolated) prior to purging or as soon as possible after purging begins.

12. Record water quality parameter measurements (temperature, pH, specific conductance, dissolved oxygen, oxidation/reduction potential, and turbidity) using the in-line flow cell. Take readings every 3 to 5 minutes.

13. Stop purging when the following parameters have stabilized for three successive readings or when at least one well casing volume has been purged:

    - Temperature: ±1 degree Celsius;
    - pH: ±0.1 unit;
    - Specific conductance: ±10 percent; and
    - Dissolved oxygen or turbidity: ±10 percent.

The data shall be recorded on a Ground Water Sample Collection Data Form for each well and temporary sampling point that is sampled. The Field Data Collection Form will document the following information, at a minimum:

- FID and/or PID measurements in the head space;
- Decontamination procedures;
- Initial depth to water;
- Purge method and rate;
- Physical parameters of the purged water;
- Depth-to-water measurements during purging;
- Volume of water purged prior to sample collection; and
- Disposal method of purged water.

Evacuated well water will be placed into a 55-gallon drum or portable tank and stored on site in a secured area until disposal. A drum log shall be completed each time a drum is used. Necessary precautions shall be taken to prevent spilling of drummed water, and drums or portable tanks shall not be left overnight at well locations outside a fenced area at the site.

3.2.3 Ground Water Sample Collection

After the well-purging criteria are satisfied, ground water sample collection can begin. The following sampling procedure is to be followed at each well:

1. Label sample containers (see section 4.2.1 for instruction).

2. Don clean nitrile or powderless surgical gloves immediately before obtaining sample.

3. Disconnect the in-line flow cell and collect samples directly into sample bottles. Maintain a slow linear flow with as little aeration as possible. Samples should be collected in the following order, as applicable:

   a. Volatile natural attenuation samples.

   b. VOC samples. Each volatile organic analysis (VOA) sample vial will be completely filled so the water forms a convex meniscus at the top to ensure that no air space exists in the vial after the vial has been capped. After filling, the vial will be immediately capped, turned over, and tapped to check for trapped air. If air bubbles are observed, the vial will be opened and filled again with sample water. If bubbles are still present, the vial will be discarded.

   c. Semivolatile organic samples. Fill the sample containers to the base of the bottle neck.

   d. Inorganic natural attenuation samples. For dissolved inorganic samples, place a 0.45-micron filter in line with the pump discharge tubing to remove particulates prior to collecting the samples in preserved sample containers. Fill the sample containers to the base of the bottle neck.

4. After each sample is collected, place the bottles in self-sealing plastic bags and immediately place the bags in a chilled cooler with ice or frozen ice packs.

5. Record sample number, time of sampling, location, and sampler name on the Ground Water Sample Collection Data Form and COC form.

6. If using a non-dedicated pump, remove pump and tubing from well, discard disposable tubing, and decontaminate the pump as described in Section 5.0.

7. Replace well cap, close well cover, and lock well.

8. Complete the COC form for transportation of samples to laboratory.

9. Hand deliver or ship samples to the laboratory on the same day they are collected, or as soon afterwards as possible.

3.2.4 *Quality Assurance/Quality Control Samples*

To identify potential errors, four types of QC samples may be included for analysis. All QC samples are labeled and sent to the laboratory along with the actual samples for analysis. The four types of QC samples are described in the following sections.

3.2.4.1 *Trip Blanks*

Trip blanks check for contamination due to handling, transport, contact with other samples during storage, or laboratory error. A VOA bottle set is filled with deionized water by the laboratory. This set is taken to the field, labeled with company name, date, and cooler ID, and stored with the other samples until they are delivered for analysis to the laboratory. Trip blanks are opened by laboratory personnel only. One trip blank set is sent per cooler of samples for volatiles analysis per day.

3.2.4.2 *Field Duplicates*

Sometimes referred to as a split or replicate, a field duplicate is a check on field and laboratory precision. Two consecutive samples are filled at the same sampling location. One is labeled as the actual well sample and the other is labeled as a duplicate sample. Preservation and shipping of samples and their duplicates are identical. One duplicate will be submitted per 10 samples, or one per sampling event if fewer than 10 samples are collected.

3.2.4.3 *Rinsate Samples*

Equipment rinsate blanks verify that chemicals are not being carried from one sample to the next when non-disposable equipment is being used for sample collection. The non-disposable equipment is first decontaminated with deionized water. Deionized water is then poured through the decontaminated equipment into sample bottles.

Rinsate samples will not be collected for wells to which specific or disposable sampling equipment (bailer or pump) has been dedicated, as no likelihood of transferring chemicals to other samples exists.

3.2.4.4 *Matrix Spikes*

Matrix spikes are used to assess precision and accuracy of the analytical method on various matrices. For this procedure, duplicate samples are collected at a well and spiking is done by the laboratory. Samples are labeled as matrix spikes for the laboratory.

4.0 SAMPLE HANDLING

4.1 CONTAINERS, PRESERVATION, AND HOLDING TIMES

Certified clean sample containers and trip blanks will be obtained from the contract analytical laboratory. The bottles will be labeled to indicate the type of analysis to be performed, and necessary preservatives will be present in the bottles when received from the laboratory.

Table 1 summarizes the sampling containers, preservation, and holding times for the potential types of analyses.

4.2 SAMPLE TRACKING

Documents for tracking the samples are generated in the field. This documentation includes field notes, sample labeling, and COC forms.

4.2.1 Sample Labeling

Each sample will be labeled prior to collection. The sample label will be filled out with waterproof ink. At a minimum, each sample label will contain the following information:

- Company name;
- Site/project name;
- Sample number (well location);
- Parameters for analysis;
- Date and time of collection;
- Preservative; and
- Sampler's signature (or initials).

Information pertinent to field survey measurements (water level, pH, specific conductivity, and temperature) and sampling will be recorded on the Ground Water Sample Collection Data Forms and/or in the field notebook. The ERM field staff is responsible for the data sheets and notebook.

4.2.2 *Chain-of-Custody Forms*

A COC form will be filled out in the field and will accompany every shipment of samples to the analytical laboratory. The purpose of the COC form is to document possession of a sample from the time of collection in the field to its final disposal by the laboratory.

Each COC form will contain the following information:

- Company name;
- Site/project name and number;
- Sample identifications;
- Requested analysis for each sample;
- Date and time of sample collection;
- Preservative; and
- Sampler's name and signature.

The laboratory will enter the following information on the COC form once the samples have been delivered to the laboratory:

- Name of persons receiving the sample;
- Date of sample receipt; and
- Sample condition.

All corrections to the COC record will be initialed and dated by the person making the corrections.

Each COC form will include signatures of the appropriate individuals indicated on the form. The originals will follow the samples to the laboratory and copies documenting each custody change will be received and kept on file by ERM. All COC forms will be maintained on file by ERM until final disposition of the samples.

5.0 EQUIPMENT DECONTAMINATION

Decontamination will be performed on all non-dedicated sampling equipment that may contact potentially contaminated water, including water level probes and flow-through cells. Clean nitrile gloves or powderless surgical gloves are to be worn during decontamination.

Each piece of non-dedicated sampling equipment will be decontaminated before use at each well. Plastic sheeting will be laid down around each well during evacuation/sampling to protect decontaminated equipment from contact with the ground. The decontamination procedure for most equipment will be as follows:

- Disassemble equipment, as appropriate;
- Wash equipment in an Alconox (or equivalent) and water solution using a brush or clean cloth to ensure removal of all contaminants;
- Rinse equipment in fresh tap water;
- Rinse again with deionized water; and
- Dry equipment with paper towel and place in clean plastic, if appropriate.

The effectiveness of these decontamination procedures will be verified by vigorous QA/QC protocols, including blanks, duplicates, and/or spikes.

6.0 INSTRUMENT CALIBRATION

Mechanical equipment used during sampling may include water quality meters, PID or FID, and pump. Before going into the field, the sampler will verify that all of these are operating properly. In addition, the water quality meters and PID/FID require daily calibration. If these field instruments require periodic recalibration by the manufacturer, they will be returned accordingly and a record will be kept of the procedure. Calibration times and appropriate readings will be recorded in the field notebook and/or on data collection forms.

7.0 DOCUMENTATION

Thorough documentation in the field is required to ensure proper labeling and tracking of samples, identify potential sources of error, and maintain accountability among field personnel.

The following information will be included in the field notes and/or on data collection forms:

General Information

- Names of personnel;
- Weather;
- Personal protective equipment used;
- Date and time of sampling;
- Location and well number;
- Condition of the well;
- Times that procedures and measurements are completed;
- Calibration of meters at start of day;
- Decontamination times;
- PID or FID readings (if taken);
- Initial static water level and total well depth; and
- Calculations (e.g., calculation of evacuated volume).

Sampling Information

- Volume of water evacuated before sampling;
- Water quality parameter measurements recorded during evacuation (note times and cumulative volume of purged water);
- General description of sample procedures;
- Time of sample collection;
- Number of samples collected;
- Order in which sample bottles were filled;
- Sample identification numbers;
- Preservation and storage of samples;
- Filtration performed, if any;

- Record of any QC samples from site;
- Any irregularities or problems that may have a bearing on sampling quality; and
- Type of sampling equipment.

Table 1 Sample Containers, Preservatives, and Holding Times for Test Parameters

Parameter	Container	Preservative	Lab Holding Times
Volatile Organic Compounds	40 ml vial with Teflon faced septa cap	Acidity to pH of <2 with hydrochloric acid. Refrigerate at 4° ±2ºC	Analysis performed within 14 days from sample collection date
Semivolatile Organic Compounds	1-liter amber glass bottles with Teflon-lined cap	Refrigerate at 4° ±2ºC	Extract within 7 days from collection date/analyze within 40 days from sample extraction date
Total Petroleum Hydrocarbons (Extractable)	1-liter amber glass bottles with Teflon-lined cap	Refrigerate at 4° ±2ºC	Extract within 7 days from collection date/analyze within 14 days from sample extraction date
Total Petroleum Hydrocarbons (Purgeable)	40 ml vial with Teflon faced septa cap	Acidity to pH of <2 with hydrochloric acid. Refrigerate at 4° ±2ºC	Analysis performed within 14 days from sample collection date
Organochlorine Pesticides	1-liter amber glass bottles with Teflon-lined cap	Refrigerate at 4° ±2ºC	Extract within 7 days from collection date/analyze within 40 days from sample extraction date
General Minerals	500 ml polyethylene vial	Varies depending on compound	Varies depending on compound
Methane, ethane, and ethene	40 ml vial with Teflon faced septa cap	Acidity to pH of <2 with hydrochloric acid. Refrigerate at 4° ±2ºC	Analysis performed within 14 days from sample collection date (hold time not specified)

Appendix C
Injection Mass and Volume Calculations

IP-1 - Silt Zone (based on SOD from pre-design bench test)

Saturated Zone Thickness	10	ft
Treatment Area	100	ft2
TCE Concentration in Water	24000	ug/l (at well MW-11B)
Porosity	46%	Feasibility Study Appendix F Geotechnical Laboratory Report (ERM 2006)
KMnO4-TCE Reaction:	$2\ KMnO_4 + C_2HCl_3 \rightarrow 2CO_2 + 2MnO_2 + 2K^+ + 3Cl^- + H^+$	
MW of TCE	131.37	lb/lbmol
MW of KMnO4	158.04	lb/lbmol
Density of 3% Permanganate Solution	8.5	lb/gal
Distribution coefficient (Kd) for aquifer matrix for TCE	1	L/kg (EPA Region 9 PRG Tables, October 2004)
Soil Oxidant Demand for Permangante	10	lb/cy (Based upon actual bench testing of site soil - at CPT-34-38; Carus Corporation 8 March 2007)

Dissolved TCE Uptake		
Dissolved TCE Concentration	24000	ug/l
Volume of Water	3450	gal.
TCE Mass	0.69	lb
TCE Mass	0.005	lbmol
Stoichiometric Permanganate Need (lb-moles)	0.01	lbmol
Stoichiometric Permanganate Need (lb)	1.66	lb
Adsorbed TCE Uptake		
Dissolved TCE Concentration	24000	ug/l
Estimated soil TCE Concentration	24000	ug/kg (or ppb)
Mass of Impacted Soil	100,000	lb
TCE Mass	2.40	lb
TCE Mass	0.018	lbmol
Stoichiometric Permanganate Need (lb-moles)	0.04	lbmol
Stoichiometric Permanganate Need (lb)	5.77	lb
Soil SOD TCE Uptake		
Volume of Impacted Soil	37.04	cy
SOD Permanganate Need (lbs)	370.37	
Pore space saturation upon injection	30%	(Based on ERM professional judgement)
Safety Factor (account for other VOCs, SOD variation)	25%	(Based on ERM professional judgement)

Total Permanganate Uptake (lb)=	**480**	lb
Total 3% Permangante Solution Uptake (gal)=	1,900	gal
Total 2% Permangante Solution Uptake (gal)=	2,800	gal
Total 1% Permangante Solution Uptake (gal)=	5,600	gal
Total 0.5% Permangante Solution Uptake (gal)=	11,300	gal

3% Single Injection Diameter (ft)=	15.3
2% Single Injection Diameter (ft)=	18.6
1% Single Injection Diameter (ft)=	26.2
0.5% Single Injection Diameter (ft)=	37.3

IP-2 - Sand Zone (based on SOD from Feasibility Study bench test)

Saturated Zone Thickness	10	ft
Treatment Area	300	ft2
TCE Concentration in Water	6300	ug/l (at wells MW-13B and TW-1)
Porosity	36%	Feasibility Study Appendix F Geotechnical Laboratory Report (ERM 2006)
KMnO4-TCE Reaction:	$2\ KMnO_4 + C_2HCl_3 \rightarrow 2CO_2 + 2MnO_2 + 2K^+ + 3C1^- + H^+$	
MW of TCE	131.37	lb/lbmol
MW of KMnO4	158.04	lb/lbmol
Density of 3% Permanganate Solution	8.5	lb/gal
Distribution coefficient (Kd) for aquifer matrix for TCE	1	L/kg (EPA Region 9 PRG Tables, October 2004)
Soil Oxidant Demand for Permangante	0.75	lb/cy (Feasibility Study, Appendix C - Chemical Oxidation Treatability Study (ERM 2006)

Dissolved TCE Uptake		
Dissolved TCE Concentration	6300	ug/l
Volume of Water	8100	gal.
TCE Mass	0.43	lb
TCE Mass	0.003	lbmol
Stoichiometric Permanganate Need (lb-moles)	0.01	lbmol
Stoichiometric Permanganate Need (lb)	1.02	lb
Adsorbed TCE Uptake		
Dissolved TCE Concentration	6300	ug/l
Estimated soil TCE Concentration	6300	ug/kg (or ppb)
Mass of Impacted Soil	300,000	lb
TCE Mass	1.89	lb
TCE Mass	0.014	lbmol
Stoichiometric Permanganate Need (lb-moles)	0.03	lbmol
Stoichiometric Permanganate Need (lb)	4.55	lb
Soil SOD TCE Uptake		
Volume of Impacted Soil	111.11	cy
SOD Permanganate Need (lbs)	83.33	
Pore space saturation upon injection	30%	(Based on ERM professional judgement)
Safety Factor (account for other VOCs, SOD variation)	25%	(Based on ERM professional judgement)

Total Permanganate Uptake (lb)=	**120**	lb
Total 3% Permangante Solution Uptake (gal)=	500	gal
Total 2% Permangante Solution Uptake (gal)=	700	gal
Total 1% Permangante Solution Uptake (gal)=	1,400	gal
Total 0.5% Permangante Solution Uptake (gal)=	2,800	gal

3% Single Injection Diameter (ft)=	8.9
2% Single Injection Diameter (ft)=	10.5
1% Single Injection Diameter (ft)=	14.8
0.5% Single Injection Diameter (ft)=	21.0

IP-2 - Silt Zone (based on SOD from pre-design bench test)

Saturated Zone Thickness	10	ft
Treatment Area	100	ft2
TCE Concentration in Water	6100	ug/l (at well MW-13A)
Porosity	46%	Feasibility Study Appendix F Geotechnical Laboratory Report (ERM 2006)
KMnO4-TCE Reaction:		$2\ KMnO_4 + C_2\ HCl_3 \rightarrow 2CO_2 + 2MnO_2 + 2K^+ + 3C1^- + H^+$
MW of TCE	131.37	lb/lbmol
MW of KMnO4	158.04	lb/lbmol
Density of 3% Permanganate Solution	8.5	lb/gal
Distribution coefficient (Kd) for aquifer matrix for TCE	1	L/kg (EPA Region 9 PRG Tables, October 2004)
Soil Oxidant Demand for Permangante	10	lb/cy (Based upon actual bench testing of site soil - at CPT-34-38; Carus Corporation 8 March 2007)

Dissolved TCE Uptake		
Dissolved TCE Concentration	6100	ug/l
Volume of Water	3450	gal.
TCE Mass in Water	0.18	lb
TCE Mass in Water	0.001	lbmol
Stoichiometric Permanganate Need in Water (lb-moles)	0.00	lbmol
Stoichiometric Permanganate Need in Water (lb)	0.42	lb
Adsorbed TCE Uptake		
Dissolved TCE Concentration	6100	ug/l
Estimated soil TCE Concentration	6100	ug/kg (or ppb)
Mass of Impacted Soil	100,000	lb
TCE Mass in Soil	0.61	lb
TCE Mass in Soil	0.005	lbmol
Stoichiometric Permanganate Need in Soil (lb-moles)	0.01	lbmol
Stoichiometric Permanganate Need in Soil (lb)	1.47	lb
Soil SOD TCE Uptake		
Volume of Impacted Soil	37.04	cy
SOD Permanganate Need (lbs)	370.37	lb
Pore space saturation upon injection	30%	(Based on ERM professional judgement)
Safety Factor (account for other VOCs, SOD variation)	25%	(Based on ERM professional judgement)

Total Permanganate Uptake (lb)=	**470**	lb
Total 3% Permangante Solution Uptake (gal)=	1,800	gal
Total 2% Permangante Solution Uptake (gal)=	2,800	gal
Total 1% Permangante Solution Uptake (gal)=	5,500	gal
Total 0.5% Permangante Solution Uptake (gal)=	11,100	gal

3% Single Injection Diameter (ft)=	14.9
2% Single Injection Diameter (ft)=	18.6
1% Single Injection Diameter (ft)=	26.0
0.5% Single Injection Diameter (ft)=	37.0

Appendix D
CPT/MIP Logs

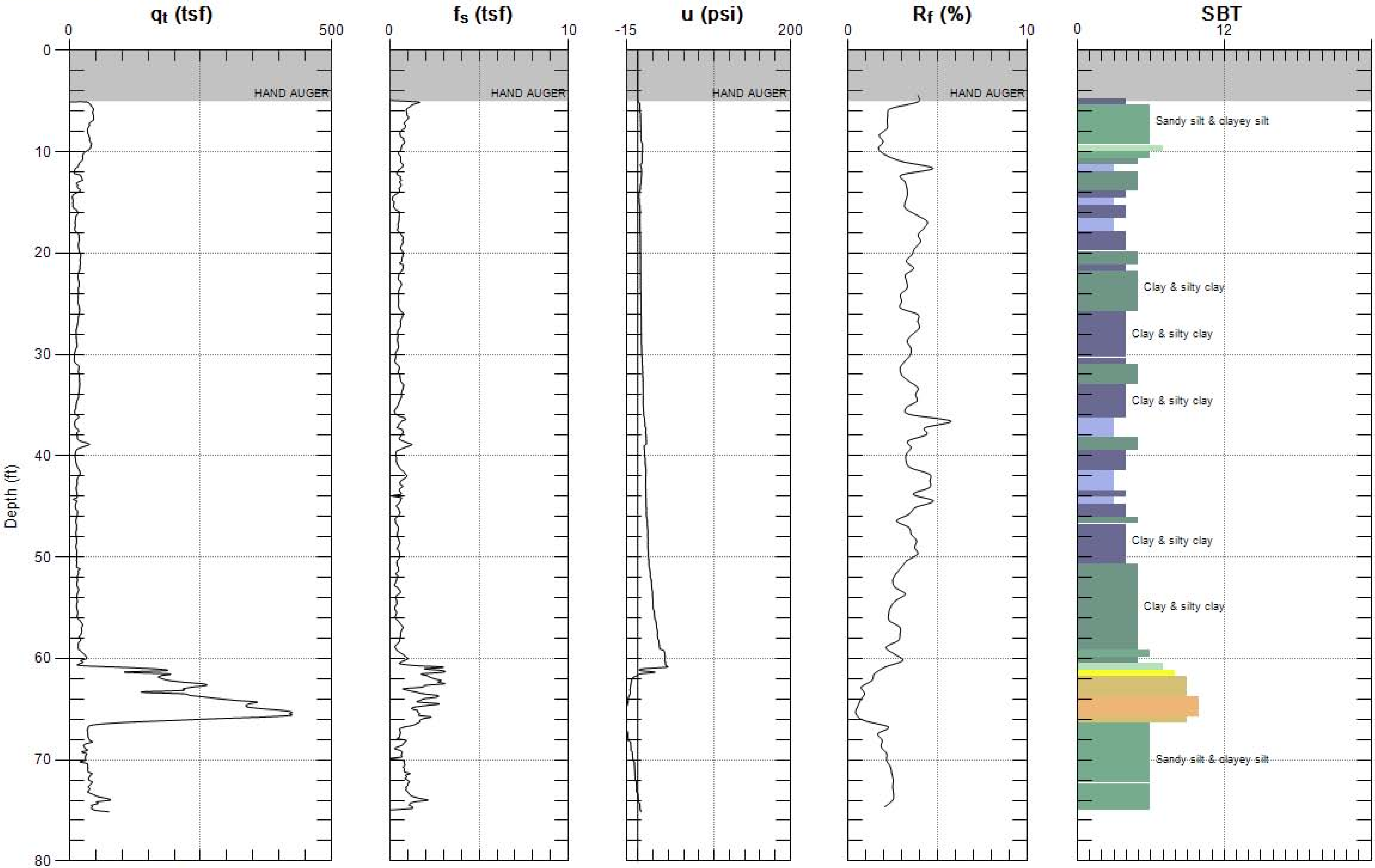
GREGG ERM

Site: HOOKSTON STATION

Engineer: D.MOBERG

Sounding: CPT-34

Date: 2/12/2007 01:40

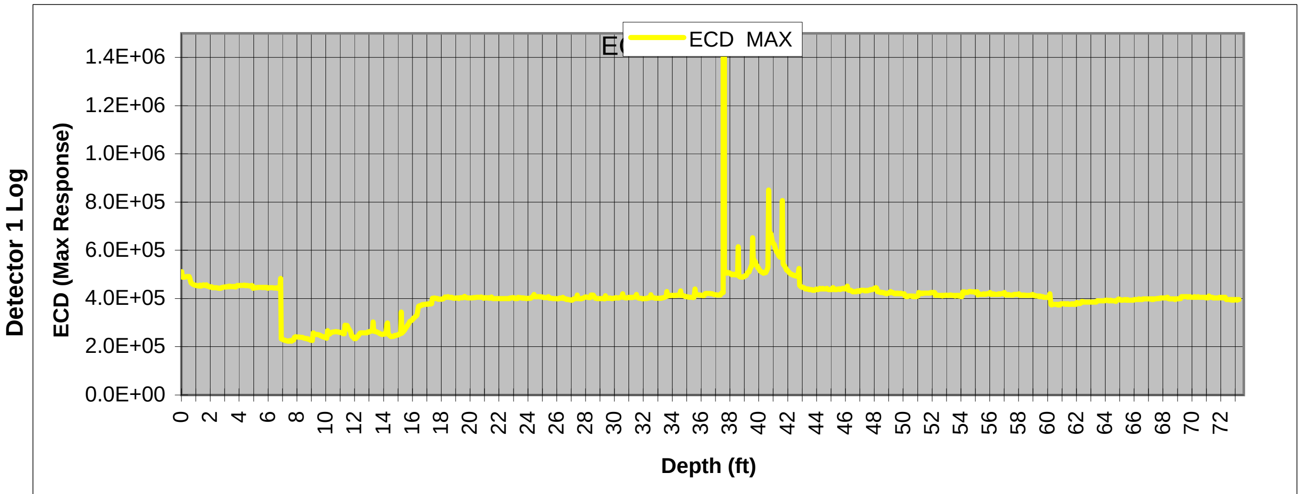


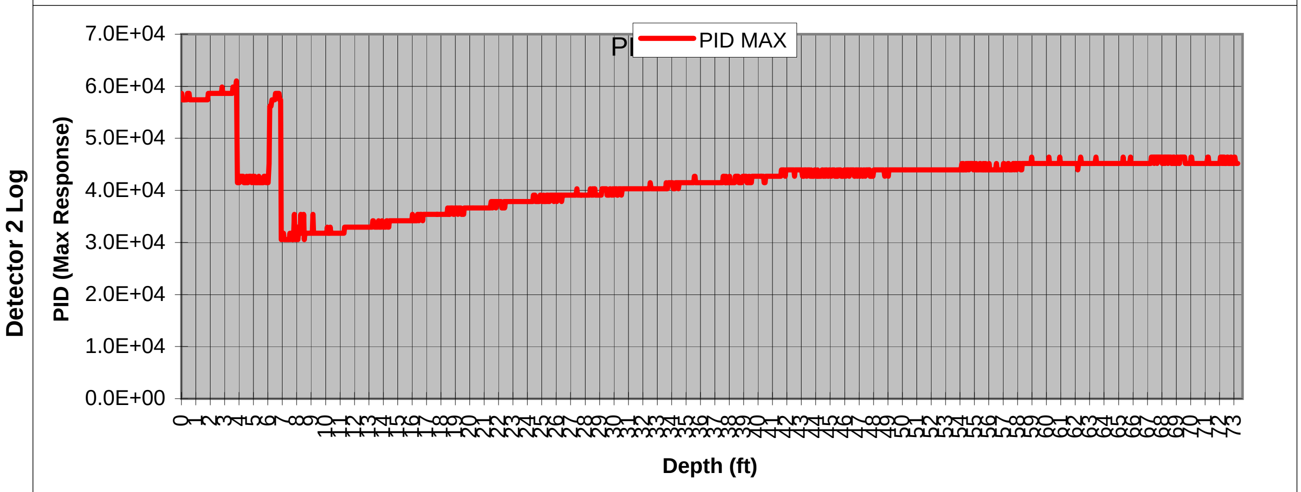
Max. Depth: 75.130 (ft)
Avg. Interval: 0.656 (ft)

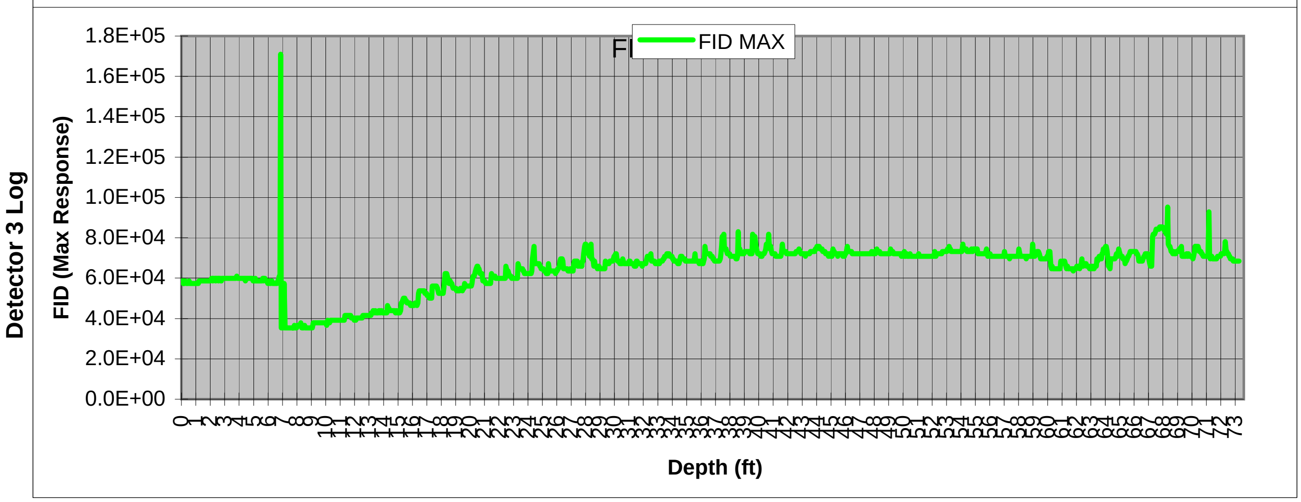
SBT: Soil Behavior Type (Robertson 1990)

MIP Log Results by Boring - Detector Reading vs. Depth

Client:	ERM	Boring I.D.:	CPT-34	Detector 1 :	Electron Capture (ECD
		Date:	Feb 12 2007	Detector 2 :	Photo Ionization (PID)
		Time:	14:48	Detector 3 :	Flame Ionization (FID)

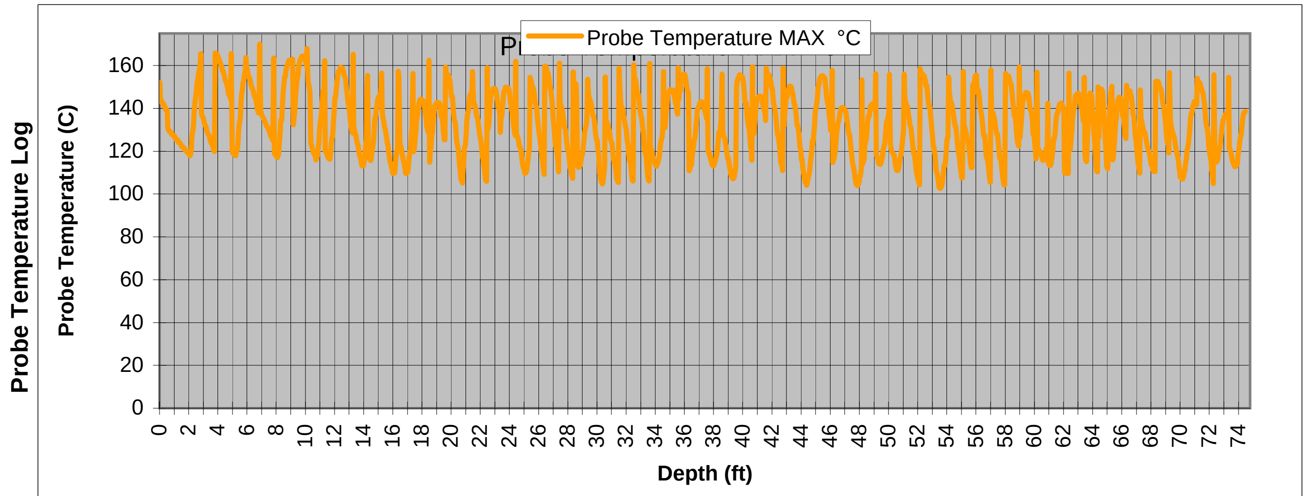


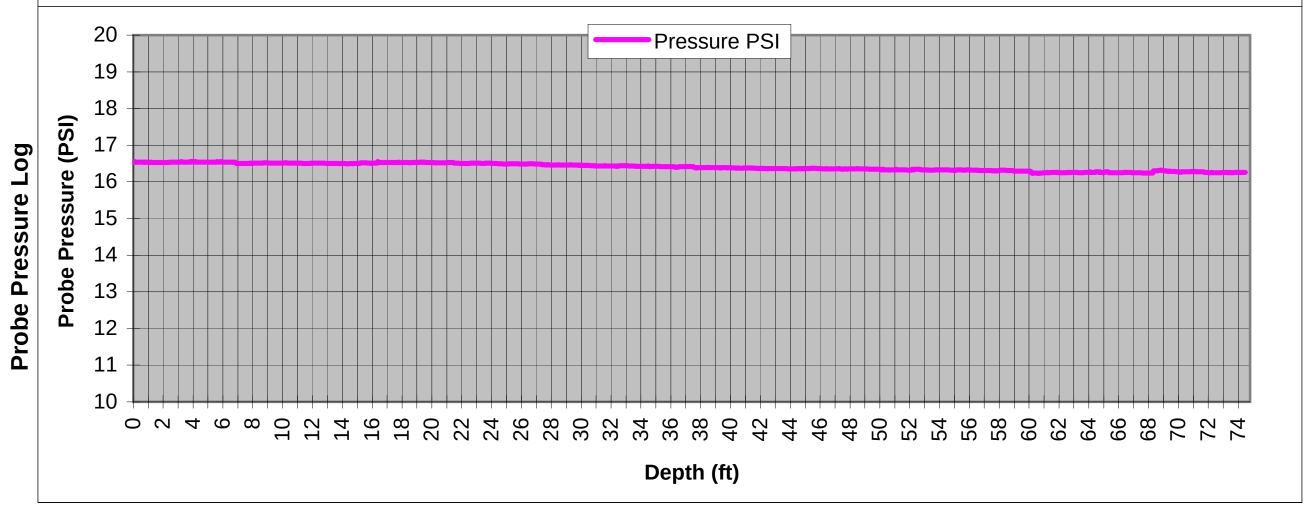




MIP Log Results by Boring - Detector Reading vs. Depth

Client:	ERM	Boring I.D.:	CPT-34	Graph 1 :	Probe Temperature (C
		Date:	Feb 12 2007	Graph 2 :	Probe Pressure (PSI)
		Time:	14:48		





Explanation: Hand augered to 5' bgs. Attenuation error at 40.55'. Disregard data. PID lamp went out at approximately 9' bgs. FID signal at 9' caused by opening the system to check PID lamp.

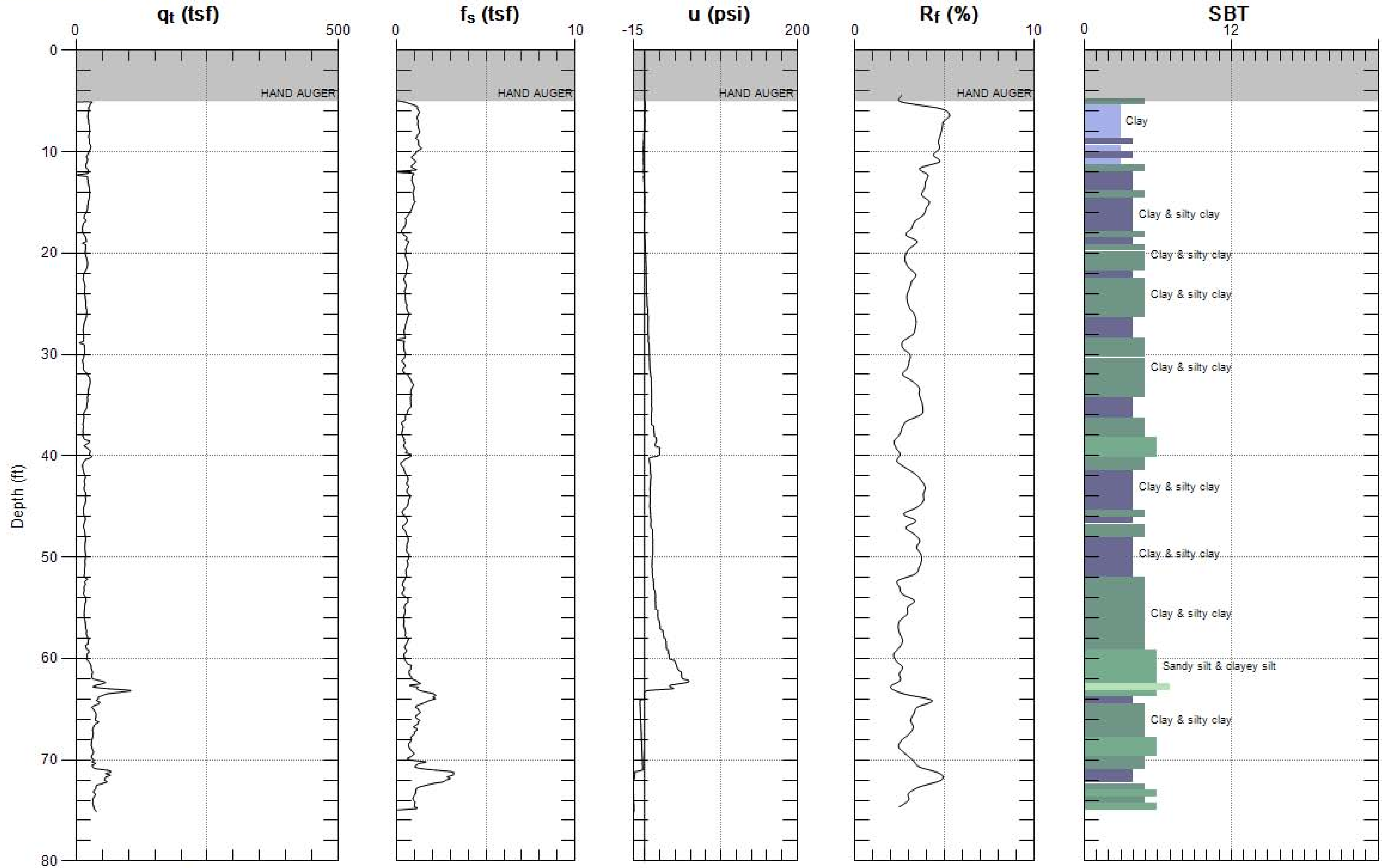
GREGG ERM

Site: HOOKSTON STATION

Sounding: CPT-35

Engineer: D.MOBERG

Date: 2/13/2007 08:21

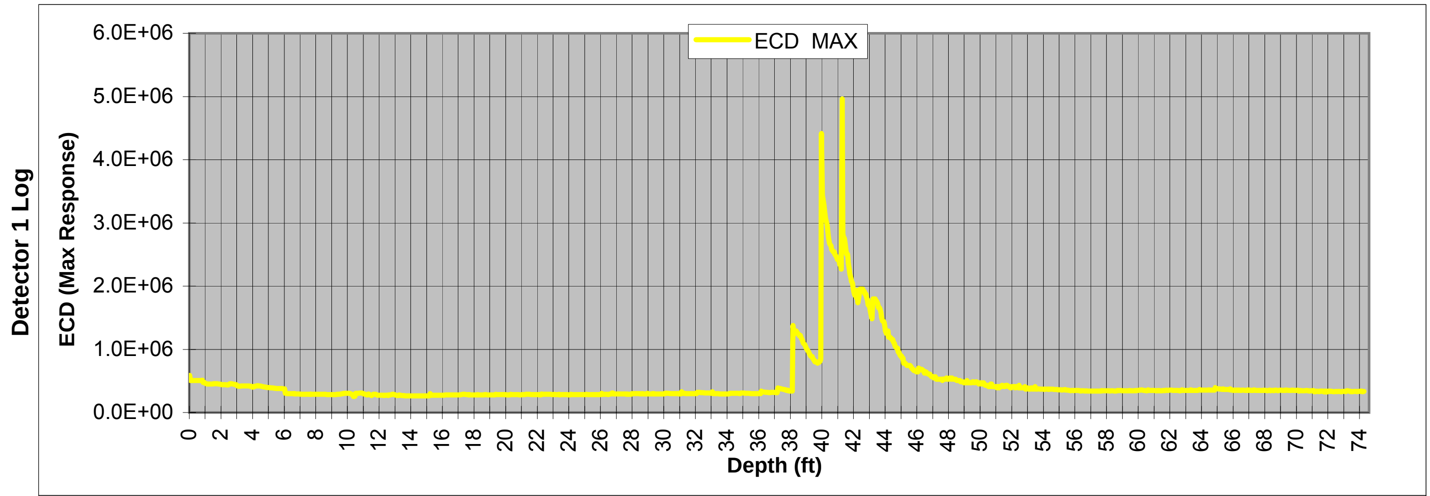


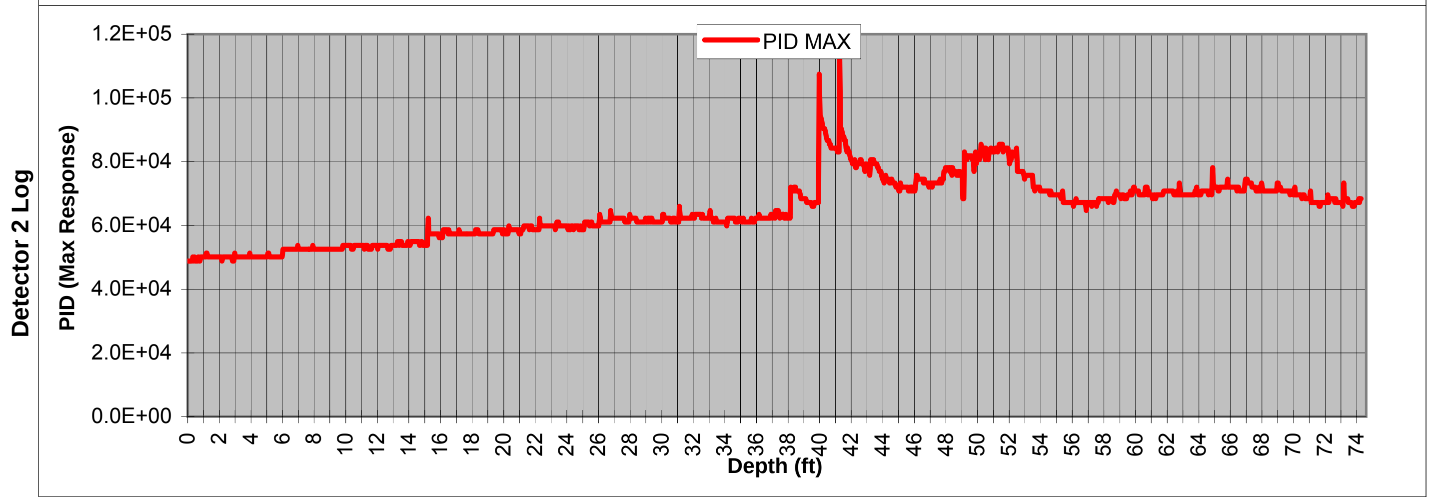
Max. Depth: 75.130 (ft)
Avg. Interval: 0.656 (ft)

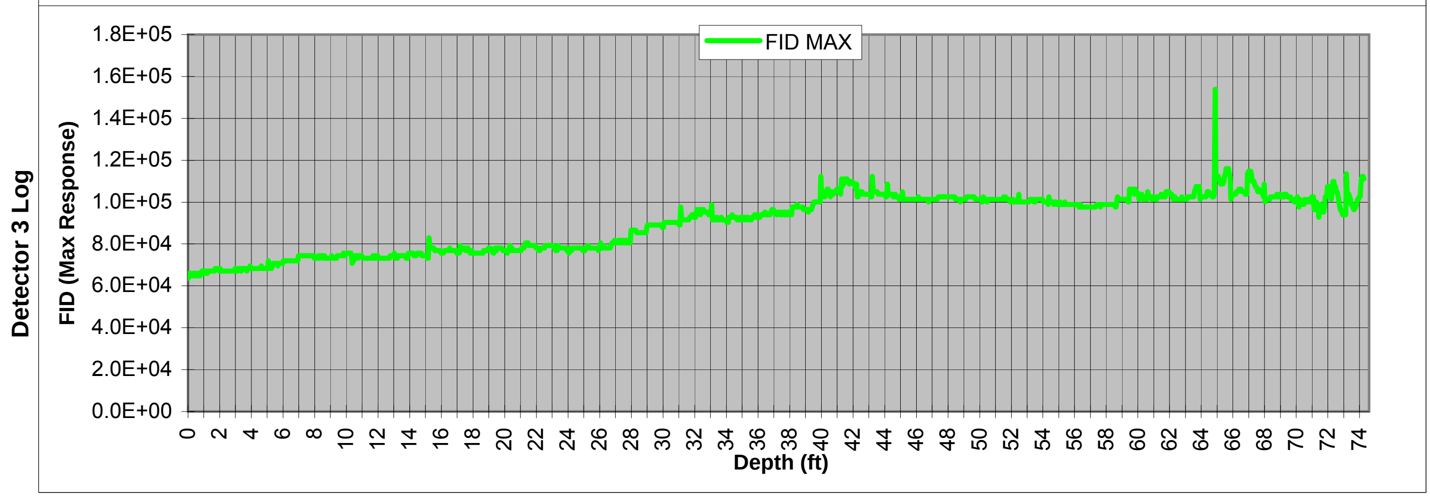
SBT: Soil Behavior Type (Robertson 1990)

MIP Log Results by Boring - Detector Reading vs. Depth

Client:	ERM	Boring I.D.:	CPT-35	Detector 1 :	Electron Capture (ECD)
		Date:	Feb 13 2007	Detector 2 :	Photo Ionization (PID)
		Time:	09:12	Detector 3 :	Flame Ionization (FID)

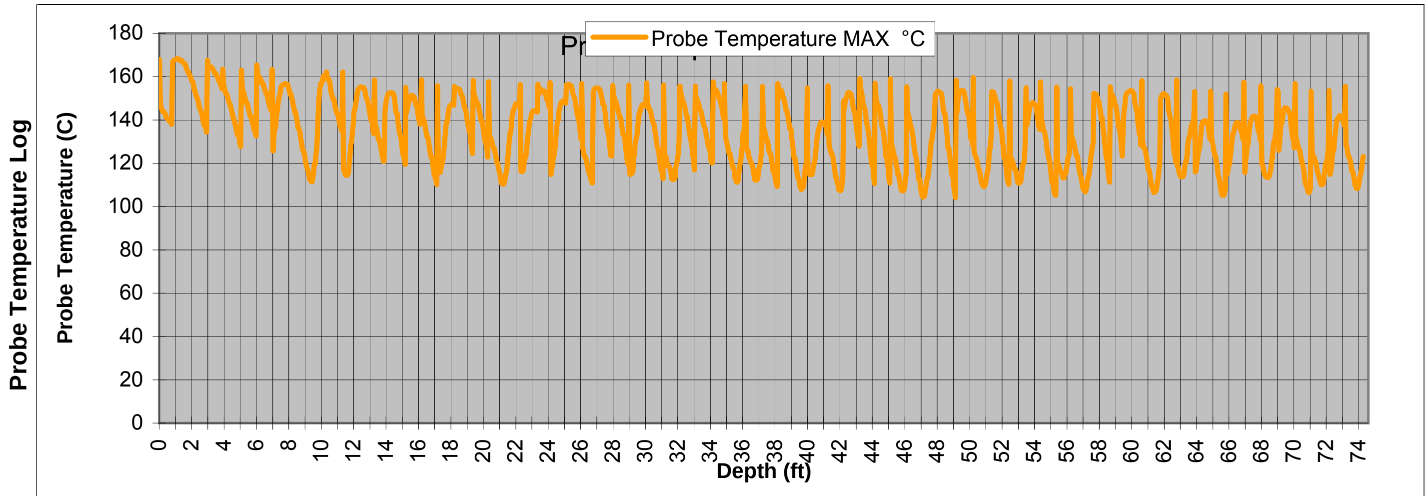


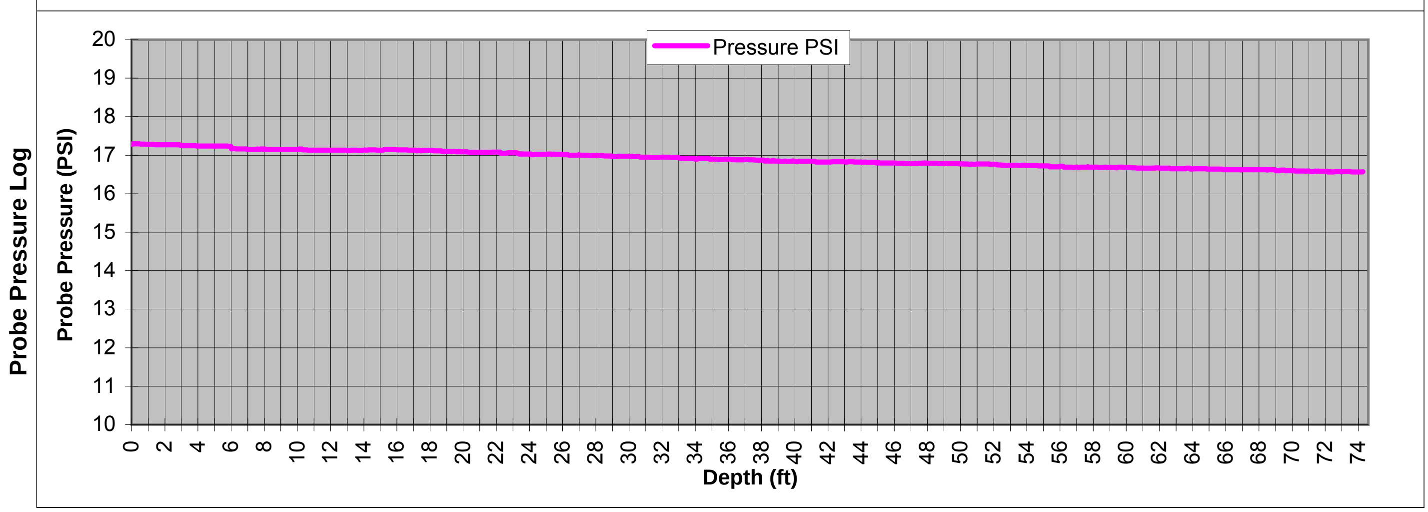




MIP Log Results by Boring - Detector Reading vs. Depth

Client:	ERM	Boring I.D.:	CPT-35	Graph 1 :	Probe Temperature (C)
		Date:	Feb 13 2007	Graph 2 :	Probe Pressure (PSI)
		Time:	09:12		





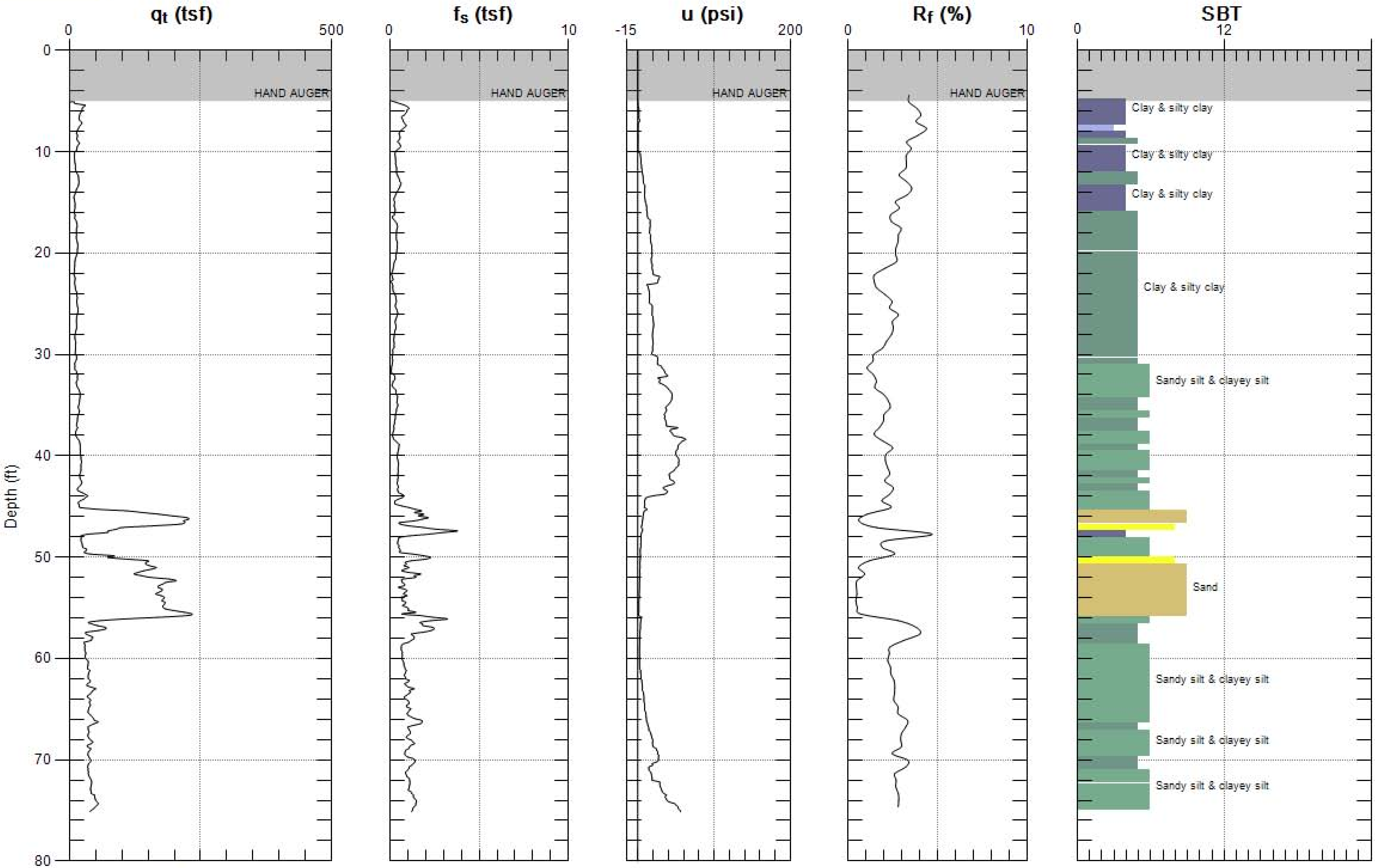
Explanation: Hand augered to 5' bgs.

GREGG

ERM

Site: HOOKSTON STATION **Engineer: D.MOBERG**

Sounding: CPT-48 **Date: 2/19/2007 01:09**

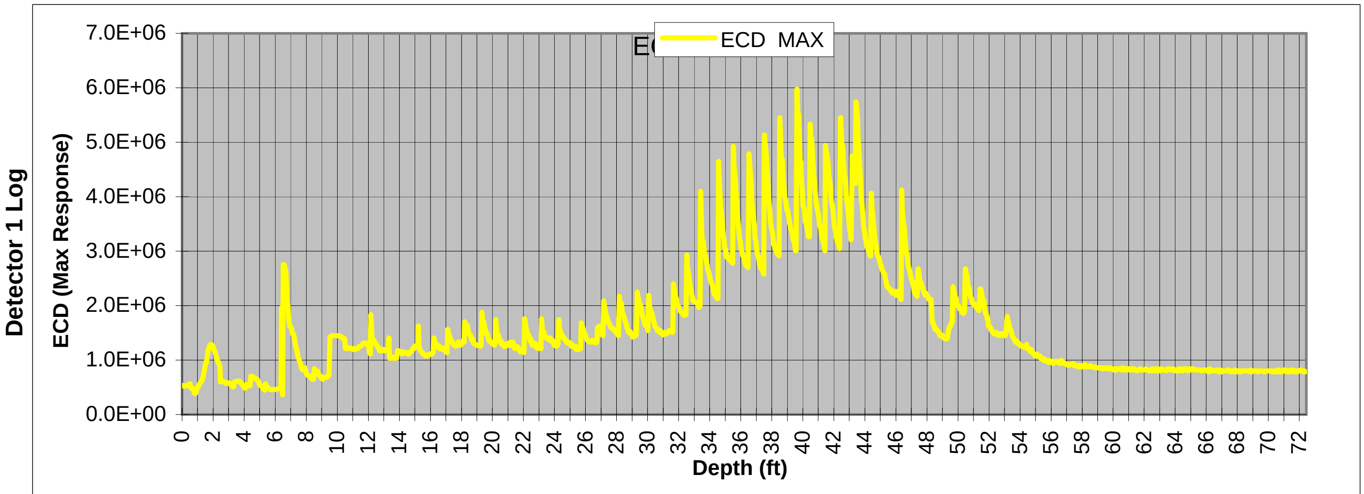


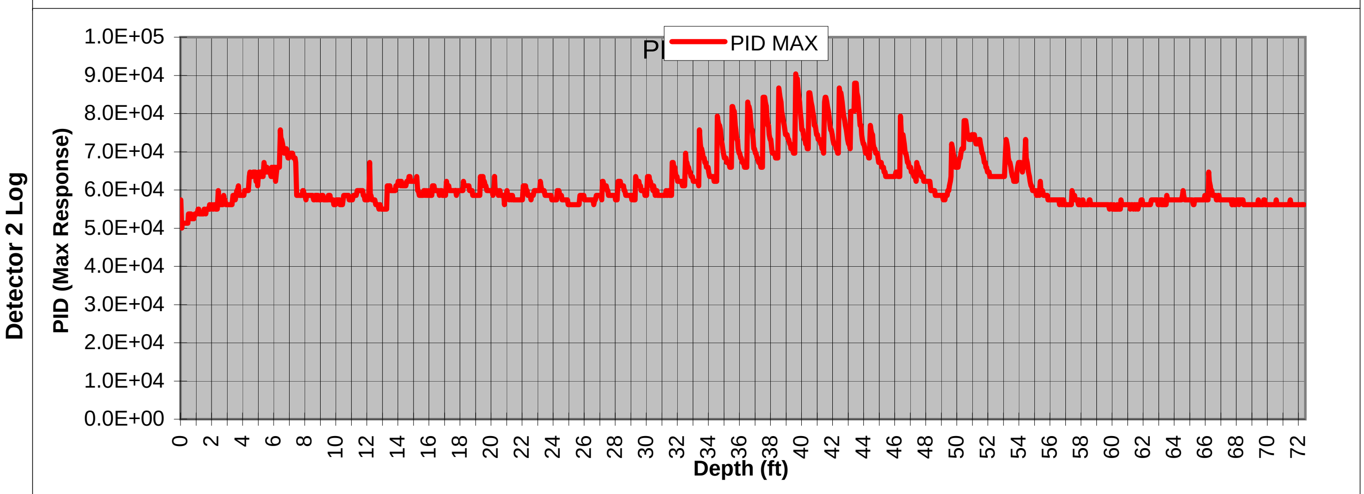
Max. Depth: 75.130 (ft)
Avg. Interval: 0.656 (ft)

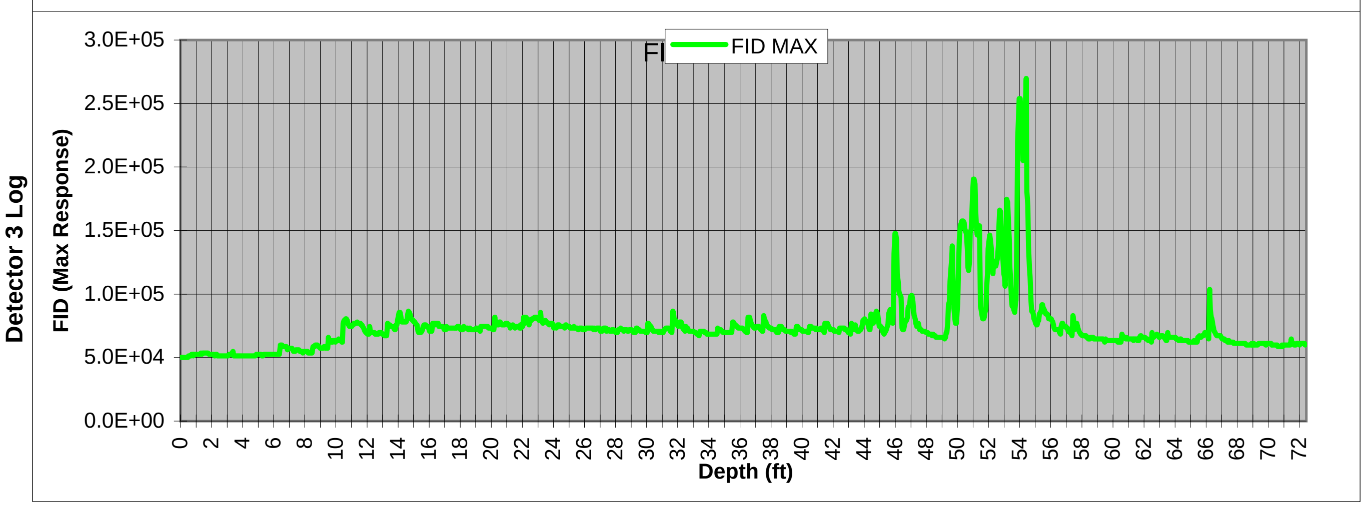
SBT: Soil Behavior Type (Robertson 1990)

MIP Log Results by Boring - Detector Reading vs. Depth

Client:	ERM	Boring I.D.:	CPT-48	Detector 1 :	Electron Capture (ECD)
		Date:	Feb 19 2007	Detector 2 :	Photo Ionization (PID)
		Time:	13:50	Detector 3 :	Flame Ionization (FID)

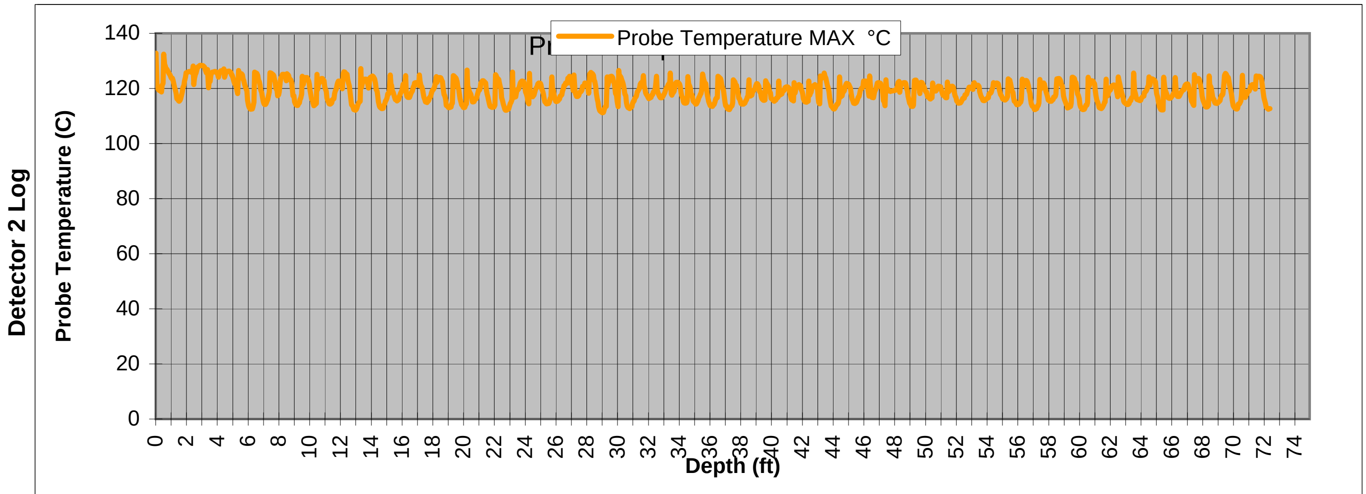


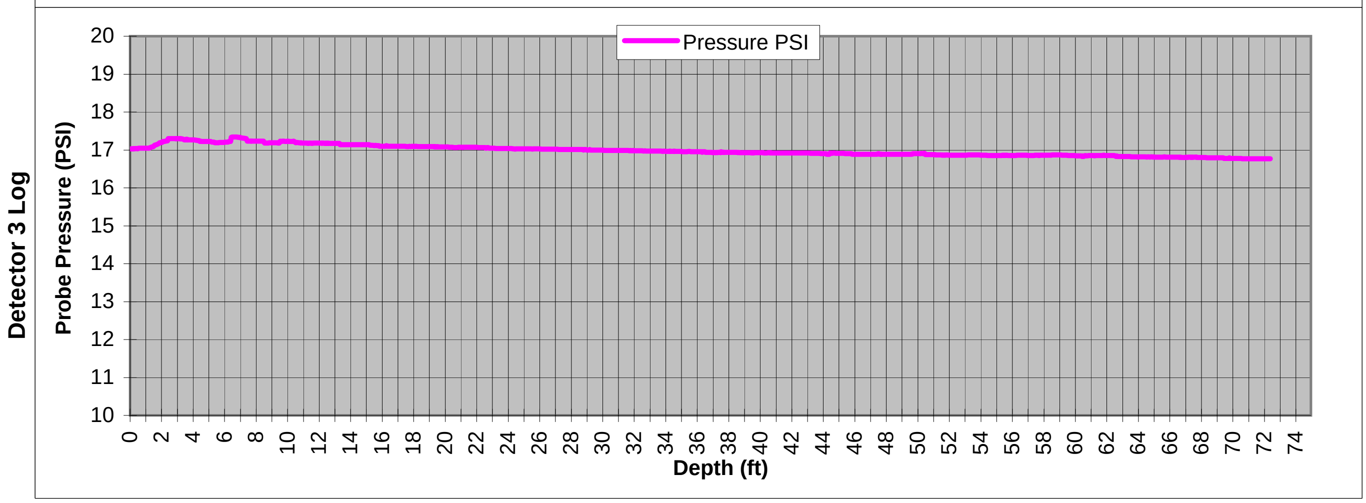




MIP Log Results by Boring - Detector Reading vs. Depth

Client:	ERM	Boring I.D.:	CPT-48	Graph 1 :	Probe Temperature (C)
		Date:	Feb 19 2007	Graph 2 :	Probe Pressure (PSI)
		Time:	13:50		





Explanation: HA to 5'. Trigger off at 22.65' per Gregg Drilling request. Restarted in one minute and equilibrated for 80 seconds.